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The Canadian Entomologist

VOLUME XCIII   **AUGUST, 1961**   **NUMBER 8**

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The Canadian Entomologist

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ACKNOWLEDGMENTS

The Canadian Entomologist

Insects and Mites Associated with Hot Spots in Farm Stored Grain[1]

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Hot spots may develop quickly in farm stored grain under Canadian winter conditions. Heavy infestations of mites, insects and fungi may accompany such hot spots (Stirrett and Arnott, 1933; Watters, 1955). Once the heating process is initiated, whatever its cause, it brings about a rapid deterioration of grain, through charring of kernels, and reduction of their germinability, and by providing optimum conditions for the growth and reproduction of storage fungi, insects and mites.

In the Prairie Provinces, individual farmers have experienced heavy losses from heating grain. This has happened particularly during 1950-58 when high crop yields forced them to store grain for longer periods than customary.

This report is part of a project undertaken in 1957 to determine the role of insects, mites and fungi in the initiation, growth and development of hot spots in farm stored grain. The clarification of the relative roles of these organisms is a necessary step for devising more effective control measures and for improvement in storage practices.

The purpose of this paper is to describe the physical conditions of a typical hot spot, record all the species of insects and mites which are commonly associated with several hot spots, and finally to single out the most common and dominant fauna occurring in this biotic community. The time evolution of populations of insects, mites and fungi associated with various stages of the heating process will be reported in a future communication.

Materials and Methods

The present report is based on a study of approximately 1500 samples, each weighing 150 g., collected from heating, stored grain in 13 farm granaries in Manitoba and Saskatchewan during 1957-60. Twelve were located on farms within a radius of 51 miles from Winnipeg, Manitoba. Thirty samples were also collected from stored barley at Glaslyn, Saskatchewan, in May, 1960, which had heated but had subsequently cooled.

Hot Spots I to VII (Tables I and II), and the surrounding grain mass were studied in detail and are referred to as experimental hot spots in this paper. A small number of samples were taken from 11 other hot spots which were examined only superficially.

In Hot Spots I to V the grain bulks were sampled in the following manner: a circular plot, nine ft. in diameter, was marked out to include the entire surface of the hot spot and most of the cooler grain mass surrounding it (Fig. 1). Each plot was sub-divided into two concentric circles, three and six ft. in diameter. Four sampling locations, 90° apart, were chosen on each circle. At each of the 13 locations (A to M, Fig. 1) samples were taken at approximately two to three inches below the surface, and at depths of one, two, three, four, five and six feet,

HOT SPOTS I to V
SAMPLING DEPTHS

A to M — 1/4, 1, 2, 3, 4, 5, 6 FEET

HOT SPOT VI
SAMPLING DEPTHS and TIME

A and M – 1/4, 1, 2, 3, 4, 5 FEET, WEEKLY
G, GH, H, and L – 1/4, 3, 5 FEET, WEEKLY

HOT SPOT VII
SAMPLING DEPTHS and TIME

I to 9 – 1 and 3 FEET, MONTHLY
10 to 25 – 1 FOOT, MONTHLY
A to E – 1/4, 1, 2, 3, 4, 5, 8 FEET, BIMONTHLY
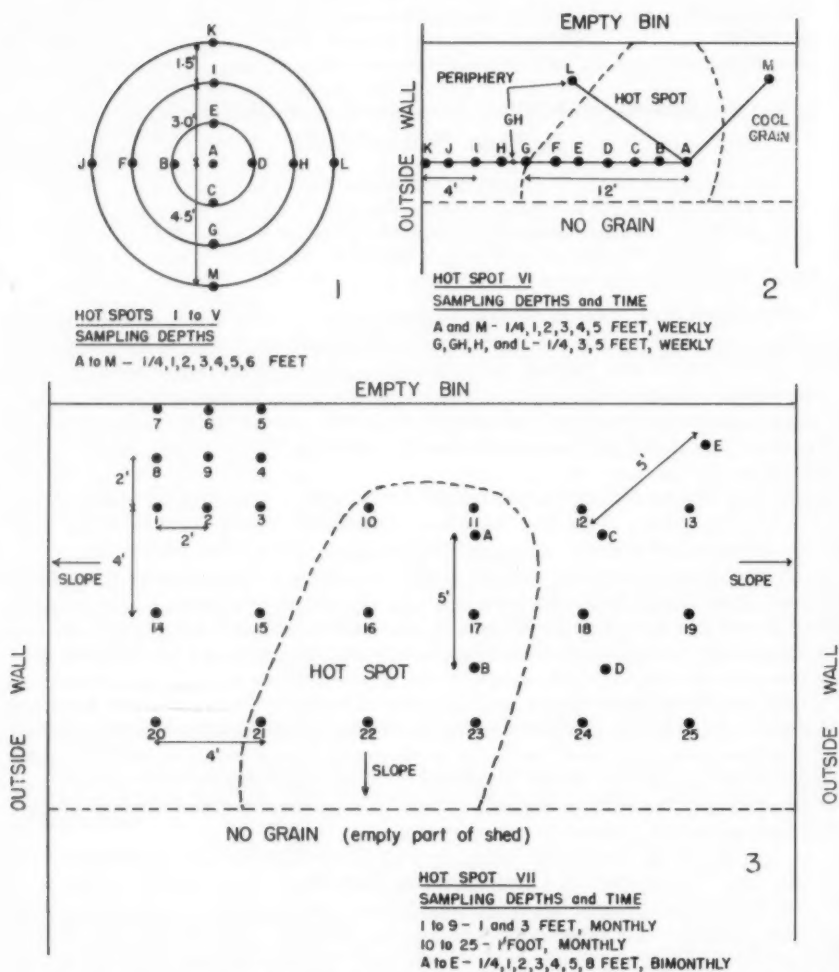
Fig. 1-3. Plan views of sampling points in grain bulks in which Hot Spots I to VII occurred.

depending upon the height of the grain bulk. The sampling patterns of Hot Spots VI and VII are illustrated in Figs. 2 and 3.

The grain samples were collected with a brass torpedo probe, 15 in. long with an outside diameter of 2 in. The probe was filled to its capacity of 150 g. for each sample.

Grain temperature and water content were measured at all sampling points (Figs. 1-3). In each sample, the adults and larvae of insects and mites were identified and the total numbers of each species were recorded. Temperature was measured to within ± 1°C. with copper-constantan thermocouples in conjunction with a potentiometer (Rubicon Co., Philadelphia, Serial No. 68684). The water content was determined within 0.2% with a dielectric moisture meter
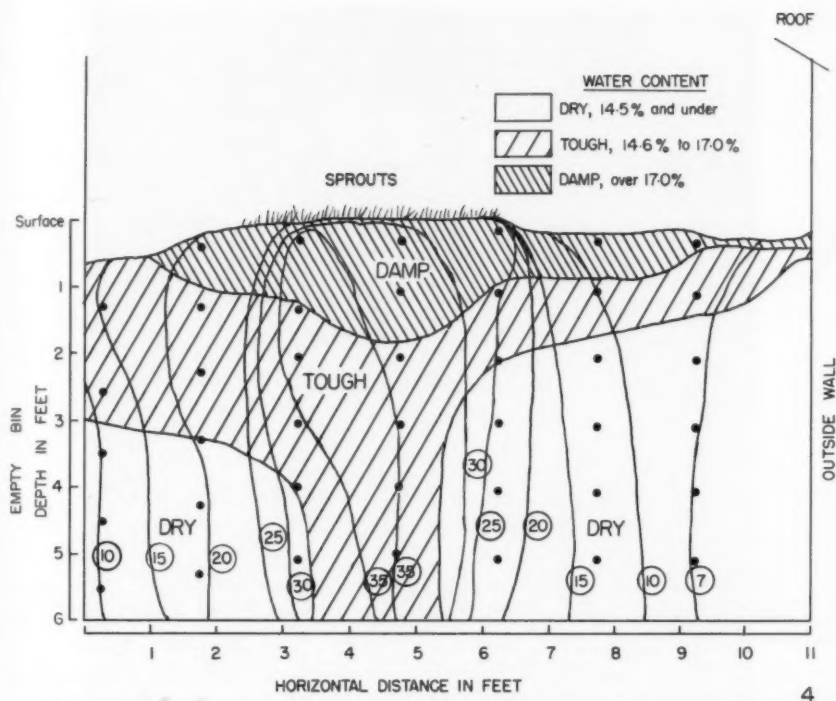
Fig. 4. A vertical cross section of the wheat bulk including Hot Spot I. The circled figures on the isotherms are expressed in centigrade.

(Halross Instruments Corps. Ltd., Winnipeg, Manitoba, Model No. 919, Serial No. 157014). Small Berlese funnels were placed under 100 watt incandescent electric bulbs for 24 hours to extract the insects and mites from each sample.

The efficiency of extraction of six major species of insects and mites was determined by counting the number of individuals extracted from 150 g. grain samples each artificially infested with 50 individuals of one species. The efficiencies of extraction from the five grain samples were as follows: *Cryptolestes ferrugineus* Steph., adults, 82-100%; *Oryzaephilus surinamensis* (L.), adults, 82-92%; *O. surinamensis*, larva, 72-92%; *Cheyletus eruditus* (Schr.), 62-88%; *Glycyphagus destructor* Schr., 82-100%; *Haemolaelaps casalis* (Berlese), 78-80%; *Tydeus interruptus* Thor., 44-60%.

Results

A description of Hot Spot I (Table I) will give an idea of the physical conditions prevailing within and around a fully developed hot spot in a small bulk of farm stored grain. A vertical cross-section through the entire length of the wheat bulk is given in Fig. 4 in which the hot spot is located slightly towards the left of the centre of the bulk.

The two most easily recognizable characteristics of the surface of the bulk associated with a hot spot are the formation of a hard crust and the presence of germinating grain at the surface above the heated mass of grain (Fig. 5). Often, during very cold weather, a continuous stream of water vapour rises from the crust but is not apparent at the periphery of the hot spot.
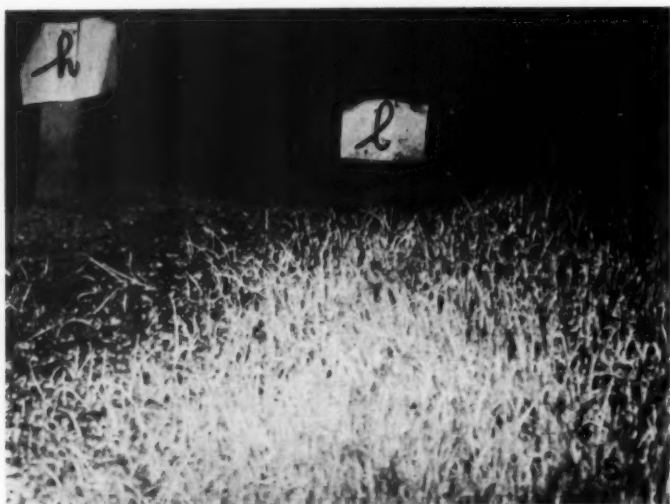
Fig. 5. Sprouting grain at the surface of Hot Spot I.

The grain mass in the hot spot from the surface to the bottom of the bulk was mouldy. These moulds were mainly *Penicillium*, *Aspergillus*, *Absidia*, and Actinomycetes.

The hottest area of the bulk was immediately below the surface of sprouting grain (Fig. 4); the isotherms, 25°C. and 35°C., with gradients as high as 20°C. per foot, enveloped the core of the hot spot. The narrow zone between these two isotherms may be regarded as a boundary separating the fully developed hot spot from the surrounding cooler grain mass. There was an abrupt drop in the mean number of *Cryptolestes ferrugineus*, the major insect species, from 122, in 13 samples taken from inside the core, delimited by the isotherms 25°C. to 35°C., to 7 in 17 samples collected from the grain mass immediately outside the 25°C. isotherm.

Generally, the grain temperature increased with increasing depth within the hot spot as well as in the cooler grain along its periphery. However, this was not the case in grain within one or two feet from the outer wall as shown by the isotherms 7° and 10°C.

The temperature of the grain mass closest to the outside wall is given by the 7° isotherm (Fig. 4). Low grain temperatures within two feet of the wall were due to outside weather conditions.

Uneven distribution of water content in grain is one of the most important physical characteristics of a hot spot. Adopting the current grading system (Milner, *et al.*, 1947) the grain within Hot Spot I and its surrounding areas has been divided into three categories on the basis of its water content: "damp" (about 17%); "tough" (14.6% to 17%); and "dry" (below 14.6%). These three layers of grain are shown in Fig. 4. The central inflated part of the damp layer, up to 21 inches thick, constitutes the upper portion of the hot spot. This layer, however, extended beyond the hot spot along the surface and its thickness gradually diminished towards the periphery. A layer of tough grain surrounded the damp layer and included the rest of the hot spot. The grain mass, made up
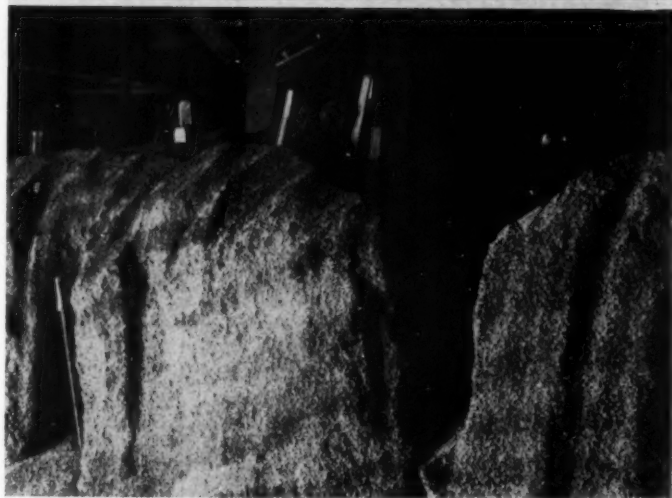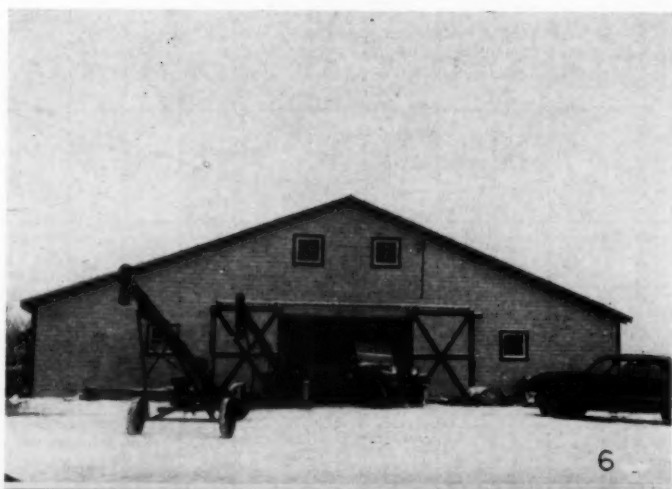
Fig. 6.   Machine shed in which Hot Spot II developed.
Fig. 7.   Hot Spot II after removal of the sprouting and surrounding grain mass.

of the tough and damp layers, had the shape of a mushroom, its trunk constituting the core of the hot spot.   Finally, a layer of dry grain surrounded the affected grain mass.

There was a high density of adults, and immature forms of insects and mites, within the hot spot, particularly in the damp grain immediately below the sprouting surface.   Insect density was greatly reduced in the cooler grain mass surrounding the hot spot.   There were no immature insects in these areas.

Detailed ecological information of ten hot spots from seven granaries is summarized in Table I.   The shape as well as the sampling patterns of all hot spots investigated in detail are illustrated respectively in Figs. 1, 2, 3 and 7.

TABLE I

Details of Grain Bulks in Which Hot Spots were Studied Within 51 Miles of Winnipeg, Manitoba, During 1957-60

Hot Spot	Storage[a]				Grain Variety	Period of Storage yr.	Approx. Quantity of Grain, bu.	Max. Depth of Bulk, ft.	Sampling Dates	No. of Times Sampled	Temp. of Cool Grain °C.c	Max. Temp. in Hot Spot °C.
	Type	Floor	Wall	Roof								
I	Barn	Cracked Concrete	Wooden	Wooden	Wheat, Selkirk	1	1000	6	Jan., 1958	1	7°	39°
II	Machine Shed b	Earthen	"	"	"	1&2	2000	6	"	1	5°	53°
III	"	"	"	"	"	1&2	800	4-5	Jan.-Feb. 1958	2	6°	26°
IV	Barn	Earthen	"	"	Oats, Ajax & Garry	1	2000	8	Nov. 1957	1	14°	44°
V	"	"	"	"	"	1	1000	5	Dec. 1957	1	21°	54°
VI	Machine Shed b	Concrete	Aluminium & wood	Aluminium & wood	Oats, Rodney	2/3	15000	8	Feb.-May 1959	15	-12°	15°
VII	"	"	"	"	"	1/2	17000	9	Jan.-May 1960	10	-8°	38°
VIII	Barn	"	Wooden	Wooden	Wheat, Selkirk	1	5000	6	July-Aug. 1960	3	5°	35°
IX	"	"	"	"	"	1&2	3000	7	March 1958	2	10°	37°
X	Wooden Granary	"	Aluminium & wood	Aluminium & wood	"	1/4 & 1	1000	6	Dec. 1959	1	6°	18°

[a] An illustrated description of different types of grain storage in the Prairie Provinces of Canada is given by Watters (1959).

[b] See Fig. 6.

[c] Temperature of the grain along the distant periphery at the time of the discovery of the hot spot.

TABLE II
Frequency of Occurrence of Insects and Mites in 1254 Samples
of Stored Grain from 7 Hot Spots and the Surrounding Grain Mass

Species	Per Cent Occurrence								
	Wheat	Oats	Hot Spots, Wheat			Hot Spots, Oats			
			I	II	III	IV	V	VI	VII
Coleoptra									
Anthicidae									
Anthicus floralis (L)		1				*	12		
Cucujidae									
Cryptolestes ferrugineus Steph.	62	26	93	76	30	59	61	25	49
C. ferrugineus Steph., Larvae	52	23	66	58	38	71	80	9	26
Oryzaephilus surinamensis (L.)	0	38						34	55
O. surinamensis (L.), Larvae	0	15						2	34
Lathrididae									
Coninomus constrictus (Gyll.)	0	1				*	16		
Enicmus minutus (L.)	0	0.3					6	*	
Lathridius bergrothi Reitt.	2	0	5						
Silvanidae									
Ahasverus advena Waltl.	22	8	52	22	2	12	69	2	7
A. advena, Larvae	17	4	48	6	2	5	57		2
Tenebrionidae									
Tribolium confusum Duv.	*	0	*						
Hemiptera									
Anthocoridae									
Xylocoris galactinus (Fieb.)	1	2	3			*	31		
Hymenoptera									
Bethylidae									
Cephalonomia waterstoni Gahan.	40	1	80	13	34			1	2
Psocoptera									
Atropidae									
Lepinotus reticulatus Endl.	6	4	18	.	2	17	*	4	13
Acarina									
Ameroseiidae									
Ameroseius sp.	0	0.5							1
Cheyletidae									
Cheletomorpha lepidopterorum (Shaw)	0	5						9	3
Cheyletus eruditus (Schr.)	13	8	39	6		8	12		17
Cunaxidae, undetermined	0	0.7							2
Laelaplidae									
Haemolaelaps glasgowi (Ew.)	14	0	51						
H. casalis (Berlese)	16	30		41	7			32	37
Tydeidae									
Tydeus interruptus Thor	5	41	7	6				45	49
Troglyphidae									
Acarus siro (L.)	10	1	35						4
Glycyphagus destructor Schr.	34	42		14	74	54	96	53	21
No. of samples	260	994	71	85	104	78	49	468	399

*Occured in one sample only.

Table II shows that five out of 11 species of insects, collected from hot spots in farm stored grain, occurred in both wheat and oats. The five species are listed in the following order according to their frequency of occurrence: *Cryptolestes ferrugineus* Steph., *Ahasverus advena* Waltl, *Cephalonomia waterstoni* Gahan, *Lepinotus reticulatus* Endl., *Xylocoris galactinus* (Fieb.).

Cryptolestes ferrugineus was by far the most common insect species encountered in heating grain. Besides being present in seven experimental hot spots (Table II) it occurred in nine out of eleven other hot spots examined dur-

ing 1957-60. It was most frequently encountered in samples of the three hot spots found in wheat and in half of the four hot spots found in oats (Table II). Sixty-eight of 71 samples of Hot Spot I contained *C. ferrugineus*. In the Oat Hot Spots VI and VII (Table II) *C. ferrugineus* ranked second to *O. surinamensis* in frequency of occurrence. The larvae of *C. ferrugineus* were found in all experimental hot spots and were the most common immature insects in Hot Spots I-V; they ranked second in Hot Spots VI and VII. The highest number of individuals of this species recorded per sample was 480 in wheat (Hot Spot I) and 656 in oats (Hot Spot VII). These numbers were exceeded only by those of *O. surinamensis* in a few samples of Hot Spot VII.

Ahasverus advena was present in some samples of all experimental hot spots (Table II). Although it rarely exceeded *C. ferrugineus* in frequency of occurrence, *A. advena* was almost always present in samples containing *C. ferrugineus*. *A. advena* was found in 22 per cent of the wheat and eight per cent of the oat samples. This may be of little significance since the species occurred in 52 per cent of all samples in wheat in Hot Spot I and in 69 per cent in oats in Hot Spot V. The presence of larvae and adults in all the hot spots except VI (Table II) may indicate that the species was multiplying in certain areas in both oats and wheat. Generally, larvae of *A. advena* were less abundant than adults in samples taken from the hot spots. The maximum number of individuals per sample was 66, in wheat, Hot Spot I, and 218 in oats, Hot Spot II.

Cephalonomia waterstoni, although present in both oats and wheat samples, was more common in wheat than in oat samples; 40 per cent of wheat samples contained this species. Since *C. waterstoni* is a well known parasite of larvae of *Cryptolestes ferrugineus* (Rillet, 1946; Finlayson, 1950), its presence in samples may be limited by the occurrence of the host larvae. No larva of *C. waterstoni* was extracted by the Berlese funnel method. This may be due to the fact that the immature forms of the parasite grow inside the *Cryptolestes ferrugineus* larva (Rillet, 1946). The maximum number of adults of *Cephalonomia waterstoni* per sample did not exceed 25 (Hot Spot I).

Lepinotus reticulatus occurred in six out of the seven experimental hot spots (Table II). This species was equally common in wheat and oats. It was never extracted from more than one-fifth of the total samples in any hot spots. Nymphs of *L. reticulatus* were frequently found in samples containing the adults. The maximum number of individuals of *L. reticulatus* per sample, was 12 in wheat (Hot Spot I) and 6 in oats (Hot Spot VII).

Oryzaephilus surinamensis occurred only in oats and was the most important of the remaining six species of insects present in this species of cereal. Thirty-four and 55 per cent of all samples of oats collected from Hot Spots VI and VII respectively, contained adult *O. surinamensis*. It was the most common and possibly the dominant insect species in both hot spots. However, this species was not found in any of the 16 other hot spots studied. Larvae of *O. surinamensis* occurred in only two per cent of the samples in Hot Spot VI, yet 34 per cent of the 468 samples collected weekly from this hot spot over a period of four months contained adults (Tables I and II). This indicates that this species may breed only in certain ecological niches created during the heating process. The large difference in the frequency of occurrence of larvae of *O. surinamensis*, i.e. 2% and 34%, in Hot Spots VI and VII, respectively, is probably due to different developmental stages of the heating process in these two foci (last column, Table I). In Hot Spot VII, the maximum number of individuals of *O. surinamensis* per sample was 1188. This was the highest density (7.8 per gram) that was recovered from grain samples.

TABLE III

Insects and Mites not Included in Table II, but Have
Been Reported in Other Hot Spots in Farm-Stored Grain in Canada

	Grain	Locality	Authority
Coleoptra			
Curculionidae			Gray, 1932-34
Sitophilus granarius L.	Wheat, Barley	S.W. Ont.	Stirrett & Arnott, 1933
Sitophilus oryzae L.	Wheat	"	"
Cucujidae			
Cryptolestes minutus L.	Wheat	"	"
Mycetophagidae			
Typhaea fumata L.	Wheat, Barley	"	"
Typhaea sercorea L.	Wheat	So. Man.	Sinha
Cryptophagidae			
Cryptophagus sp.	Wheat	"	"
Ostomidae			
Tenebrioides mauritanicus (L.)	Wheat	S.W. Ont.	Stirrett & Arnott, 1933
Tenebrionidae			
Alphitophagus bifasciatus (Say)	Wheat, Barley	"	"
Tribolium castaneum Herbst	Wheat	"	"
Psocoptera			
Liposcelidae			
Liposcelis subfuscus Bdhd.	Wheat	So. Man.	Sinha
Hymenoptera			
Bethylidae			
Cephalonomia tarsalis (Ash.)	Barley	N. Sask.	"
Acarina			
Tetranychidae			
Bryobia praetiosa Koch	Wheat, Oats	So. Man.	Sinha
Aceosejidae			
Blattisocius tineivorus (Odum.)	Wheat	"	"
Laelaptidae			
Eulaelaps stabularis (Kol.)	Wheat	"	"
Macrochelidae			
Nothroholasipis tridentinus			
(C. & F. Can)	Wheat	"	"

Tribolium confusum Duv. occurred in only one sample in Hot Spot I
(Table I).

Lathrididae: *Coninomus constrictus* (Gyll.), *Enicmus minutus*, *Lathridius
bergrothi* Reitt. (Table II), and *Cryptophagus* sp. (Table III) appeared sporadic-
ally in a small percentage of samples in several hot spots. Since these species
have been reported (Hinton, 1946) to be, primarily, fungus feeders, their absence
in grain samples may be due to the absence of preferred species of fungi.

Anthicus floralis (L.) and *Xylocoris galactinus* (Fieb.) occurred simul-
taneously in Hot Spots IV and V. A detailed examination of these two hot
spots showed that these species were on the decline, characterized by the death
of the oat kernels and the presence of certain flora common to decaying organic
matter. The high occurrence in Hot Spot V of *A. floralis* and *X. galactinus*, 12
and 31 per cent respectively, probably reflected the final stages of the heating
process and thus may be considered as ecological indicators of the physical
environment.

Typhaea sercorea L. was found occasionally (Table III). Like *A. floralis*
and *X. galactinus* it also feeds on fungi characteristically found in declining hot
spots.

A second species of psocid, *Liposcelis sulfuscus* Bdhd. (Table III) was found
in several samples of heating wheat in Hot Spot VIII (Table I).

Besides *Cephalonomia waterstoni*, another species of parasitic wasp, *Cephalonomia tarsalis* (Ash.), was collected from a declining hot spot in barley on a farm in northern Saskatchewan (Table III).   *C. tarsalis*, an established parasite of *O. surinamensis* and *Sitophilus oryzae* (L.) (Powell, 1938) has not previously been recorded in Canada.

Of the nine species of mites recorded from seven experimental hot spots in Manitoba (Table II), five were found in both wheat and oats.   *Glycyphagus destructor* Schr. ranked first in frequency of occurrence in both types of grain and was found in 34 per cent of all wheat samples and 42 per cent of all oat samples.   This species was most common in Hot Spot V, occurring in 96 per cent of 49 samples of oats (Table II).

Tydeus interruptus Thor was second and fifth in frequency of occurrence in oats and wheat, respectively.   This species occurred in 41 per cent of the oat and in five per cent of the wheat samples.   It was absent in samples collected from Hot Spots III, IV and V.

Haemolaelaps casalis (Berlese) ranked second and third in frequency of occurrence in wheat and oats, respectively.   *H. casalis* occurred in 41 per cent of 85 samples in Hot Spot II, exhibiting thus the highest infestation by this species. Although *H. casalis* rarely occurred in large numbers in the majority of the samples, 2080 adults and nymphs were once extracted from an oat sample in Hot Spot VII, in which this species was present in 49 per cent of 399 samples.

Cheyletus eruditus (Schr.) was fourth in frequency of occurrence in both wheat and oats (Table II).   Nevertheless, it occurred in 39 per cent of 71 samples of wheat collected from Hot Spot I.   Since *C. eruditus* is a well known predator of Tyroglyphids (Norris, 1958), such as *Acarus siro* (L.), its presence in such an unusually large number of samples in Hot Spot I may be explained by an equally high frequency of occurrence of *A. siro*.   The maximum number of individuals of *C. eruditus* per sample was 85 in oats (Hot Spot VII).

Although *Acarus siro* (L.) was present in 10 and one per cent of all wheat and oat samples, respectively, it occurred only in two out of the seven hot spots studied in detail.   In collections of wheat samples from Hot Spot I, this species ranked third, having occurred in 35 per cent of 71 samples.

Of the remaining four species of mites which did not occur in both grains, *Haemolaelaps glasgowi* (Ewing) was most common in wheat.   This species was present in 51 per cent of the 71 samples in Hot Spot I, thus being its most common mite (Table II).   The maximum number of ,individuals of *H. glasgowi* per sample, was 100 in wheat (Hot Spot I).   *H. glasgowi*, which was previously recorded in stored grain in England (A. M. Hughes, in litt.) also occurred in Hot Spot IX (Table I).

Cheletomorpha lepidopterorum (Shaw) occurred in five per cent of all the oat samples but was not found in wheat (Table II).   The maximum number of individuals of this species per sample was six in oats (Hot Spot VII).

Ameroseius sp. occurred only in 0.5 per cent of the oat samples and was present in only one hot spot (Hot Spot VII) (Table II).   However, its sudden occurrence in large numbers and subsequent disappearance during certain stages of the heating process may be significant.   The maximum number of adults and nymphs of this species per sample was 544.

An unidentified species of Cunaxidae also occurred occasionally in oat samples in Hot Spot VII.   *Bryobia praetiosa* Koch was collected occasionally in small numbers, from hot spots in wheat and oats (Table III).   Since this species is a pest of various field crops (Pritchard and Baker, 1955) it could have come with the grain at the time of storage and managed to survive.

Three species of Mesostigmatid mites were also collected (Table I, Hot Spot VIII). There is no published record of their occurrence in Canada. Of these species, one *Blattisocius tineivorus* (Odum) (Hughes, 1948; Evans, 1957) has been recorded in stored grain in other countries. As far as I could ascertain, *Eulaelaps stabularis* (Koch) and *Nothroholasipis tridentinus* (C. and F. Can.) have never been recorded in stored grain in Canada or elsewhere but *E. stabularis* is known to occur in the nests and on the bodies of mice and other rodents (Baker, *et al.*, 1956).

Discussion

Of the twenty-eight species of insects and mites occurring in hot spots, ten are reported for the first time in stored grain in Canada. A review of the major Canadian entomological periodicals of the last ninety years has shown that there was no published record for the three insects, *Cephalonomia tarsalis*, *Liposcelis subfuscus*, *Xylocoris galactinus*, and seven mites, *Ameroseius* sp., *Blattisocius tineivorus*, *Eulaelaps stabularis*, *Haemolaelaps casalis*, *H. glasgowi*, *Nothroholasipis tridentinus*, and *Tydeus interruptus*.

Four of these species, *C. tarsalis* (Powell, 1938; Muesebeck, *et al.*, 1957), *B. tineivorus* (Evans, 1957; Chant, 1959), *H. casalis* and *T. interruptus* (Hughes, A. M., personal communication, 1959), have previous records of association with stored food products in other countries; of the remaining six species, two insects and four mites are recorded for the first time in stored grain.

The emergence of the rusty grain beetle, *Cryptolestes ferrugineus* and the long hairy mite, *Glycyphagus destructor* as the most common, and often the dominant insect and mite, respectively, is probably the most important fact arising from this preliminary study of the hot spots in farm stored grain.

Since "most communities are composed of a few very common species and numerous relatively rare species (certain tropical communities are exceptions)", it is necessary to recognize them at the outset and concentrate on the dominant populations (Odum, 1959). Therefore, a knowledge of the occurrence and numerical dominance of *C. ferrugineus* and *G. destructor* in most bulk grain habitats may prove to be valuable for future detailed ecological studies of hot spots in farm stored grain.

The high frequency of occurrence of the saw-toothed beetle, *Oryzaephilus surinamensis*, in hot spots in stored grain is significant. A review of literature concerning the past records of this species in stored grain in Canada revealed that it had previously occurred as a dominant species in hot spots developed in small bulks of stored oats. For example, Gilbert, on May 16, 1935 reported "A very heavy infestation of the saw-toothed beetle, *Silvanus surinamensis* (L.) in 1600 bushels of oats which had been stored in one bin since last autumn, occurred at the Agricultural College, Kemptville, Ont. The oats were heating badly". Association of this species with heated produce in warehouses in Britain was also emphasized by Howe (1956). He observed that wherever he was able to study the field ecology of *O. surinamensis*, the insect was associated with heated produce.

The granary weevil, *Sitophilus granarius* (L.) has been reported as the most common and dominant pest associated with heating grain (Gray, 1932; Stirrett and Arnott, 1933) in farmers' bins in southern Ontario. It is interesting to note that no *S. granarius* occurred in hot spots studied in Manitoba and Saskatchewan. However, it occurred sporadically in grain in the southern parts of the Prairie Provinces (Gray, 1932; Watters, 1955) where the rusty grain beetle, *Cryptolestes ferrugineus* is regarded as the most serious pest of farm stored grain. Perhaps

the severe winter climate in the Prairies serves as a deterrent to the success of *S. granarius*, as it is known to be more susceptible to cold than *C. ferrugineus* (Solomon and Adamson, 1955).

Thirty-five species of insects and mites which occur in hot spots in farm stored grain fall into five probable feeding categories:

(1) *Herbivorous* (grain or grain dust feeder). Insects, *Cryptolestes ferrugineus*, *C. minutus*, *Lepinotus reticulatus*, *Liposcelis subfuscus*, *Oryzaephilus surinamensis*, *Sitophilus granarius*, *S. oryzae*, *Tenebroides mauritanicus* (L.), *Tribolium castaneum* Hbst., *T. confusum*; mites, *Acarus siro*, *Bryobia praetiosa*, *Glycyphagus destructor*, *Haemolaelaps casalis* (?), *H. glasgowi* (?).

(2) *Fungivorous*. Insects, *Anthicus floralis*, *Ahasverus advena*, *Coninomus constrictus*, *Cryptophagus* sp., *Enicmus minutus* (L.), *Lathridius bergrothi*, *Lepinotus reticulatus*, *Typhaea stercorea*, *T. fumata* (L.), *Xylocoris galactinus* (?); mites, *Ameroseius* sp., *Blattisocius tineivorus*, and *Glycyphagus destructor*.

(3) *Predators*. Mites, *Cheletomorpha lepidopterorum*, *Cheyletus eruditus*, *Haemolaelaps casalis**, *Tydeus interruptus* (?).

(4) *Parasites*. *Cephalonomia tarsalis* (on *Sitophilus oryzae* & *Oryzaephilus surinamensis*), *C. waterstoni* (on *Cryptolestes ferrugineus*); mites (primarily parasitic on rodents but may feed on grain products or insect excreta), *Haemolaelaps casalis*, *H. glasgowi*, *Eulaelaps stabularis*.

(5) *Scavengers*. Insects, *Liposcelis subfuscus*, and *Lepinotus reticularus*; *Xylocaris galactinus* (?); mites, *Tydeus interruptus* (?). The occurrence and relative abundance of the insects and mites feeding on the above-mentioned materials during the initiation, growth and decline of a hot spot may give valuable information for future studies on the successive steps of grain decay and the incidence of various fungi associated with stored grain.

There is no doubt that some species of insects and mites have come with the grain from the field at the time of storage. Thus, the insects, *Anthicus floralis*, *Ahasverus advena*, *Lathridius bergrothi*, *Enicmus minutus*, and the mites, *Haemolaelaps casalis*, *Glycyphagus destructor* and *Tydeus interruptus* were collected from grain fields in the vicinity of Winnipeg. The remaining insects and mites were probably already present in the empty granaries, as recently shown by Liscombe and Watters (1961) and perhaps most of them started to breed under the favourable environment created by the heating grain.

Summary

A study of 18 hot spots and the surrounding grain mass, in stored wheat, oats, and barley in 13 farm granaries in Manitoba and Saskatchewan was made from approximately 1500 samples collected during 1957-60. A typical hot spot in stored wheat was illustrated and described in detail. Seventeen insect and 14 mite species are reported. Of these, three insects, *Cephalonomia tarsalis* (Ash.), *Liposcelis subfuscus* (Bdhd.) and *Xylocoris galactinus* (Fieb.) and seven mites, *Ameroseius* sp., *Blattisocius tineivorus* (Odum.), *Eulaelaps stabularis* (Koch), *Nothroholasipis tridentinus* (C. & F. Can.), *Haemolaelaps glasgowi* (Ewing), *H. casalis* (Berlese), and *Tydeus interruptus* Thor have not been previously recorded in stored grain in Canada.

On the basis of their frequency of occurrence in 1254 samples collected from seven hot spots and the surrounding grain mass in stored oats and wheat, the rusty grain beetle, *Cryptolestes ferrugineus* Steph. and the long hairy mite, *Glycyphagus destructor* Schr. emerged as the most common and probably the dominant

*In laboratory it was observed to have attacked *Glycyphagus destructor*.

insect and mite species, respectively.   The saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.), a dominant species in oats, did not occur in wheat or barley.

All the investigated insects and mites were classified into five probable feeding categories: Herbivorous (grain and grain dust feeders), fungivorous, predacious, parasitic, and scavenger.

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New Genera and Species of Rose-Infesting Aphids
(Homoptera: Aphididae)

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The two new genera and species described in this paper can be distinguished from other rose-infesting aphids in North America by means of the key given below. Specimens of *Macrosiphum nigromaculosum* Macdougall were not available for examination and this species has been worked into the key on the basis of descriptions by Macdougall (1926) and Palmer (1952).

1. Cornicles distinctly reticulated near apices 2
   Cornicles without reticulations, but some of the apical imbrications may be coalesced . 5
2. Dorsum of abdomen in alatae with a large, quadrate, pigmented patch ....
   ....*Placoaphis siphunculata*, new genus, new species
   Without a dorsal patch as above 3
3. Cornicles normally pigmented near apices ....*Macrosiphum euphorbiae* (Thomas)
   Cornicles largely dark-coloured 4
4. Cornicles as long or longer than antennal segment III; apterae with secondary sensoria; widespread ....*Macrosiphum rosae* (L.)
   Cornicles usually shorter than antennal segment III; apterae without secondary sensoria; western North America ....*Macrosiphum nigromaculosum* Macd.
5. Cornicles very short, little more than a sclerotized ring on a broad, mammiform base
   ....*Maculolachnus submacula* (Wlk.)
   Cornicles cylindrical, elongate 6
6. Normally with six setae on each first tarsal segment ....
   ....*Pseudocercidis rosae*, new genus, new species
   With fewer than six setae on each first tarsal segment 7
7. With five setae on each first tarsal segment 8
   With fewer than five setae on each first tarsal segment 10
8. Cornicles shorter than cauda ....*Longicaudus trirhodus* (Wlk.)
   Cornicles longer than cauda 9
9. Apical halves of cornicles distinctly swollen ....*Myzaphis rosarum* (Kalt.)
   Apical halves of cornicles not swollen ....*Pentatrichopus tetrarhodus* (Wlk.)
10. Apical halves of cornicles swollen ....*Wahlgreniella nervata* (Gill.)
    Apical halves of cornicles not swollen 11
11. Apterae 12
    Alatae 14
12. Frontal tubercles smooth or nearly so ....*Metopolophium dirhodum* (Wlk.)
    Frontal tubercles scabrous 13
13. With secondary sensoria ....*Rhodobium porosum* (Sand.)
    Without secondary sensoria ....*Fimbriaphis fimbriata* (Rich.)
14. Dorsum of abdomen with a quadrate, pigmented patch ....*Fimbriaphis fimbriata* (Rich.)
    Dorsum of abdomen without a patch as above 15
15. Secondary sensoria with ciliate margins ....*Rhodobium porosum* (Sand.)
    Secondary sensoria without ciliate margins ....*Metopolophium dirhodum* (Wlk.)

Pseudocercidis, new genus

Type species: *Pseudocercidis rosae* new species.

Apterous Viviparous Female.—Frontal tubercles well developed, smooth, with pointed setae. Antennae six-segmented, without secondary sensoria. First segments of tarsi each normally with six setae. Cornicle short, not much longer than cauda, with a well developed flange. Cauda short, triangular, not constricted near middle.

Comments.—This genus resembles *Amphicercidus* Oestlund, from which it can be distinguished by the well developed frontal tubercles, longer cauda and the presence of six setae on each first tarsal segment.

P. rosae   P. siphunculata
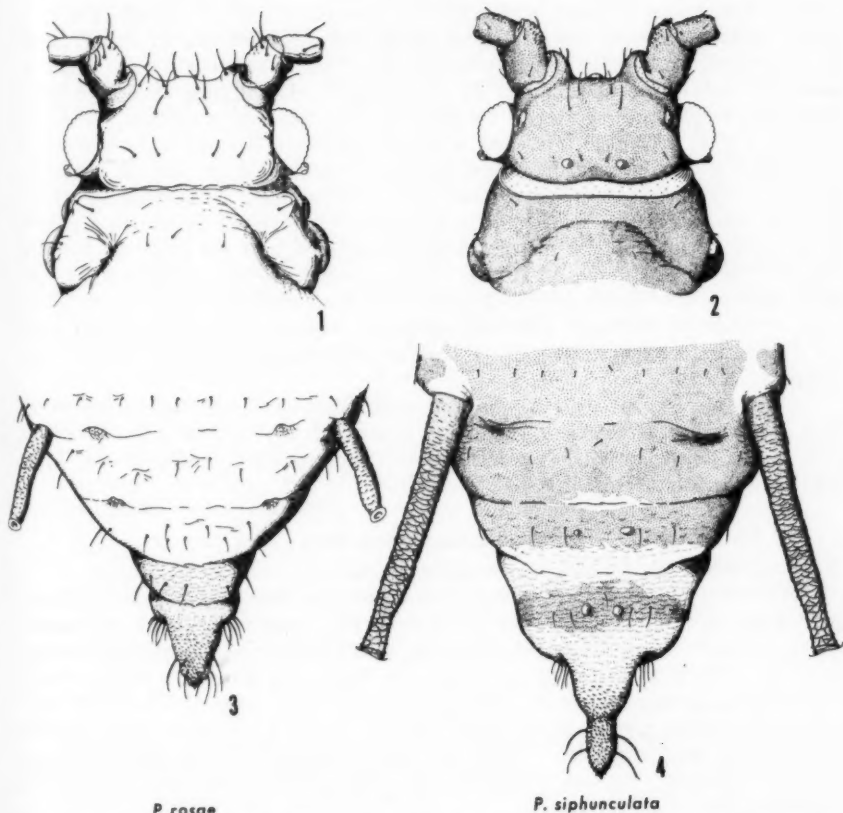
Figs. 1, 2. Dorsa of heads and prothoraxes. Figs. 3, 4. Dorsa of apical abdominal segments.

Pseudocercidis rosae, new species

Apterous Viviparous Female.—Colour in life: Not observed.   Colour when macerated: Largely yellow or light brown, apices of tibiae, whole of tarsi and apical three antennal segments darker.

Morphology: Frontal tubercles with 2-4 pointed setae, each of which is about 1½ times as long as the basal diameter of antennal segment III.   Disc of head smooth, sometimes with two median clusters of cribriform plates; with pointed setae which are about the same length as those on frontal tubercles (Fig. 1).   Antenna six-segmented, first segment faintly scabrous on mesal margin, remaining segments with smooth and faintly spiculose imbrications.   Antennal setae pointed, from ½ as long to slightly longer than the extreme basal diameter of antennal segment III.   Antennal segment III normally with one or two secondary sensoria situated 0.075-0.1 mm. from base.   Lengths of antennal segments: III, 0.55-0.75 mm.; IV, 0.35-0.4 mm.; V, 0.3-0.35 mm.; VI, $0.15 + 0.4$-0.5 mm. Rostrum reaching middle coxae; apical segment 0.125 mm. long, with 5-8 setae in addition to the usual two or three apical pairs and minute basal pair.   Legs with pointed setae.   Hind tibia 1.5-1.7 mm. long.   First tarsal segments each

normally with six setae, but hind tarsi sometimes with only five. Second segment of hind tarsus 0.2 mm. long. Prothorax with or without lateral tubercles. Dorsal prothoracic setae about the same length and shape as those on disc of head. Setae on abdominal terga I-VII pointed, about the same length and shape as those on disc of head, arranged in 7-9 irregular, longitudinal rows. Eighth abdominal tergite normally with six pointed setae. Lateral abdominal tubercles absent. Cornicle 0.2-0.25 mm. long, with spiculose imbrications, slightly swollen on apical half. Cauda short, triangular, not constricted at middle, strongly spiculose, with 1-2 pairs of lateral setae and 2-4 dorsal ones. Anal plate spiculose, with pointed setae. Genital plate with scattered spiculose imbrications; with 15-20 setae along posterior margin, 7-10 central setae and 5-8 setae on anterior margin. Abdominal terga I-VI smooth or nearly so, tergum VII sometimes with scattered spiculose imbrications, tergum VIII with strongly spiculose imbrications. Venter of abdomen with two irregular, transverse rows of pointed setae on each segment; with strongly spiculose imbrications. Length 2.25-3 mm. when mounted.

Type Material.—No. 7423 in Canadian National Collection. Holotype: Apterous viviparous female. Winnipeg, Manitoba, July 2, 1960 (A. G. Robinson) curling leaves of *Rosa* sp. Paratypes: 39 apterous viviparous females, same data as for holotype.

Placoaphis, new genus

Type species: *Placoaphis siphunculata* new species.

Alate Viviparous Female.—Frontal tubercles well developed, smooth, diverging. Disc of head usually with two tubercles near posterior margin. Antennae six-segmented. Secondary sensoria with smooth margins, restricted to segment III. Media of forewing two-branched; hind wing with two oblique veins. First tarsal segments each with three setae. Abdominal terga II-VI or VII with a large, quadrate, pigmented, sclerotic patch. Cornicle elongate, with distinct reticulations on apical half. Abdominal terga VII and VIII normally with one or two tubercles (Fig. 4). Lateral abdominal tubercles normally present on segment I-IV.

Comments.—This genus might be confused with some of the myzine genera, from which it can be readily distinguished by the presence of well developed reticulations on the cornicles. The reticulations are of the same type found in macrosiphine genera, from which *Placoaphis* can be readily distinguished by the large, pigmented, sclerotic patch on the dorsum of the abdomen.

Placoaphis siphunculata, new species

Alate Viviparous Female.—Colour in life: Not observed. Colour when macerated: Various shades of brown, the bases of the femora lighter.

Morphology: Frontal tubercles well developed, smooth, diverging, each tubercle with two or three, short, blunt setae of which the longest is about one-third as long as the basal diameter of antennal segment III. Disc of head smooth, usually with two transparent tubercles near posterior margin; anterior discal setae long and pointed, the four posterior ones short, blunt, about the same length as those on frontal tubercles. Antennae six-segmented; all segments normally with smooth imbrications. Antennal setae blunt, short, about the same length as the setae on frontal tubercles. With 8-12 secondary sensoria, each sensorium with unciliated margins. Lengths of antennal segments: III, 0.55-0.7 mm.; IV, 0.4-0.55 mm.; V, 0.325-0.45 mm.; VI, 0.15 + 0.55-0.7 mm. Rostrum not reach-

ing middle coxae, apical segment 0.12-0.15 mm. long, with 5-7 setae in addition to the usual two or three apical pairs and minute basal pair. Hind tibia 1.5-1.8 mm. long. First tarsal segments each with three setae. Second segment of hind tarsus 0.1-0.12 mm. long. Prothorax without dorsal tubercles but normally with very large lateral tubercles; dorsal setae similar in shape and size to those on frontal tubercles. Venter of pterothorax smooth. Setae on abdominal terga I-IV or V short and blunt, about the same length as those on frontal tubercles, arranged in 6-9 longitudinal rows. Setae on abdominal terga VI-VIII, pointed or blunt, about as long, or slightly longer than the basal diameter of antennal segment III. Lateral abdominal sclerites well developed, distinct on segments I-IV or V, but those on V or VI and VII joined to each other and to the dorsal pigmented patch. Cornicles 0.525-0.7 mm. long; apical ⅓ with well developed reticulations, the remaining ⅘ usually with coalescent smooth imbrications (Fig. 4). Cauda short, 0.225-0.275 mm. long, strongly spiculose, constricted near middle, with two pairs of pointed, lateral setae and usually a dorsal, preapical one. Dorsum of abdomen smooth except for spiculose imbrications on terga VII and VIII and just posterior to cornicles. Lateral sclerites with spiculose imbrications. Venter of abdomen with two, irregular, transverse rows of pointed setae on each segment. Anal plate strongly spiculose, with pointed setae. Genital plate strongly spiculose, with 9-16 blunt setae along anterior margin. Length 0.225-0.35 mm. when mounted.

Type Material.—No. 7424 in Canadian National Collection. Holotype: Alate viviparous female. Bowser, Vancouver Island, British Columbia, May 28, 1955 (R. Coyles), host unknown. Paratypes: Two alate viviparous females same data as for holotype. Three alate viviparous females, Creston, British Columbia, June 1955 (W. H. Wilde) on *Rosa* sp.

Summary

Two new genera and species of Aphididae are described. A key to the rose-infesting aphids of North America is given.

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Note on Effects of Some Minerals on Fecundity of Aptesis basizona (Grav.) (Hymenoptera: Ichneumonidae)

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Aptesis basizona (Grav.), a hymenopterous parasite of *Diprion pini* (L.), *D. similis* (Htg.), *Neodiprion sertifer* (Geoff.), and other Diprionidae in Europe, was propagated for several years at Belleville, Ont., for release in biological control programs (Green, 1938), and for use as an experimental insect. It was observed that oviposition was reduced by lack of food and by change of food from raisins to a mixture of sugars and agar (Finlayson and Green, 1940). Fecundity of the females was greater when adults were fed on fresh, unpasteurized honey than on raisins (Finlayson and Finlayson, 1957). Both raisins and honey contain protein, in the proportion of about 8:1 (Anon., 1945), so that it is unlikely to be a factor in the difference. As sugar content of raisins is about 73 per cent (Sun Maid Raisin Growers of California, *in litt.*) and of honey about 79 per cent (Watt and Merrill, 1950), it appeared that mineral trace elements or vitamins in the food might be responsible for the difference in the oviposition. Both raisins and honey contain potassium, chlorine, sulphur, calcium, phosphorus, sodium, magnesium, silica, iron, manganese, and copper, but the latter two are minor elements in raisins (Sun Maid Raisin Growers of California, *in litt.*; Apiculture Section, Entomology Research Institute, Ottawa, *in litt.*).

De Boissezon (1933) claimed that iron is important for egg development in *Culex pipiens* L., as its eggs contain iron. In a review of the nutritional requirements of insect parasites, House (1958) indicated that little work has been done on the effect of minerals in the food on the reproduction of insects. As manganese is a minor element in raisins, and as iron was known to affect the reproduction of certain insects, it was decided to test the effect of manganese sulphate and ferric citrate, separately and in combination and in various concentrations, upon the fecundity of *A. basizona* females.

The control food was composed of 0.2 gm. agar-agar, 19.8 gm. water, 10.0 gm. sucrose, and 10.0 gm. honey, a diet originally suggested by Holloway (1939). For the experimental food, various measured amounts of manganese sulphate and ferric citrate were added to the control in the proportions shown in Table I. For each test, at least 25 females were placed individually in Melrose boxes each containing a host cocoon of *N. sertifer* and a drop of the experimental food. Every two days the host cocoon was removed, dissected and examined for parasite eggs, and replaced with a fresh cocoon. This was done throughout the lifetime of each female, which often was more than two months, though oviposition was usually completed in one month. For the control, an equal number of females were similarly treated except that a drop of the control food was substituted for the experimental food. Because of difficulty in obtaining sufficient insect material at one time, and because of the length of time required to complete an experiment, the investigations conducted as a series of experiments took over two years to complete.

Concentrations of the minerals were chosen to bracket a large range, and then smaller ranges chosen to determine the optimal point. The experiments with manganese sulphate present in the food in the percentages indicated below were grouped in four series as follows: A, 0.50 with control and 0.05 with control; B, 0.08 and 0.30 with control; C, 0.01 and 0.10 with control; and D, 0.03 and 0.06 with control. Those with ferric citrate present in the food in the per-

TABLE I
Oviposition of *Aptesis basizona* (Grav.) fed on
experimental and control diets

Mineral	Series	Percentage of mineral	Experimental diet (316 females)	Control diet (323 females)
			Average number of eggs per ♀	Average number of eggs per ♀
Manganese sulphate	A	0.05	24.0	19.4
Manganese sulphate		0.50	12.8	17.3
Manganese sulphate	B	0.08	14.6	15.6
Manganese sulphate		0.30	10.9	
Manganese sulphate	C	0.01	13.1	12.6
Manganese sulphate		0.10	11.6	
Manganese sulphate	D	0.03	11.0	9.8
Manganese sulphate		0.06	11.9	
Ferric citrate	E	0.05	15.5	12.5
Ferric citrate		0.50	14.0	
Ferric citrate	F	0.10	14.4	15.6
Manganese sulphate and ferric citrate		0.05 0.05	13.0	12.9

centages indicated below were conducted in two series as follows: 0.10 with control, and 0.05 and 0.50 with control. One test was done in which 0.05 per cent of each mineral was present.

Because of the variation in the controls (see Table I), a direct comparison between the effects of the various concentrations of the chemicals is impossible. Different levels of manganese in the diet caused females to lay different mean numbers of eggs. Analyses of variance showed that statistically significant differences occurred in the mean egg number of females given different percentages of manganese sulphate in their diets for experiments A and B, but not for C and D. As the mean oviposition for 0.05 per cent is significantly greater than that for 0.50 per cent (the controls are not significantly different), and for the 0.08 per cent level is significantly greater than for 0.30 per cent, there is a suggestion that there is an optimal level for manganese dosage that is in the vicinity of 0.05 per cent. Analyses of variance showed no significant differences between treatments and controls for 0.05, 0.10, and 0.50 percentages of ferric citrate, or in a combination of 0.05 per cent ferric citrate and 0.05 per cent manganese sulphate. As 0.05 per cent manganese sulphate alone benefited oviposition, the addition of the 0.05 per cent ferric citrate in this latter case apparently inhibited oviposition.

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Limited Movement of Individuals in a Population of the Migratory Grasshopper, *Melanoplus bilituratus* (Walker) (Acrididae) at Kamloops, British Columbia[1]

By Roy L. Edwards

Recent papers by Watt (1959) and Holling (1959) have renewed interest in the use of mathematical formulae as tools in the study of population dynamics. But the usefulness of mathematical formulae can be no greater than the accuracy of the data that are fed into them and at present accurate methods of estimating insect populations are generally lacking.

Estimates made by the method of marking release and recapture, described by Lincoln (1930) and improved by later authors, depend for their accuracy on the thorough mixing of marked individuals in the wild population. The method was used by Richards (1953) to measure populations of the red locust in Tanganyika, and the purpose of the present investigation was to determine its suitability in estimating populations of the migratory grasshopper, *Melanoplus bilituratus* (Walker).

Materials and Methods

The experiments were carried out during the period August 7th - 17th, 1960, on the rangeland eight miles north of Kamloops, B.C. at an altitude of 2300 feet. The vegetation was extremely dry — only 1.31 inches of rain having fallen since April 1st — but in the hollows it still retained its green coloration. *M. bilituratus* congregated in these hollows where it formed 95 per cent of the total grasshopper population.

One of these hollows which measured 2800 square metres and contained numerous species of grasses and other plants was chosen for the experiment. Over most of the experimental area the vegetation was sparse and only 5 - 10 cm. high but at the northwest side there was a small patch of tumbling mustard almost one metre in height. Two rows of stumps placed 5 metres apart down the centre of the experimental area divided it into two approximately equal zones with a narrow band between them. (Fig. 1).

The experiment consisted of collecting adult *M. bilituratus* in each zone separately, marking them with cellulose paint to indicate date and zone of collection and releasing them individually from a single point in the centre of the
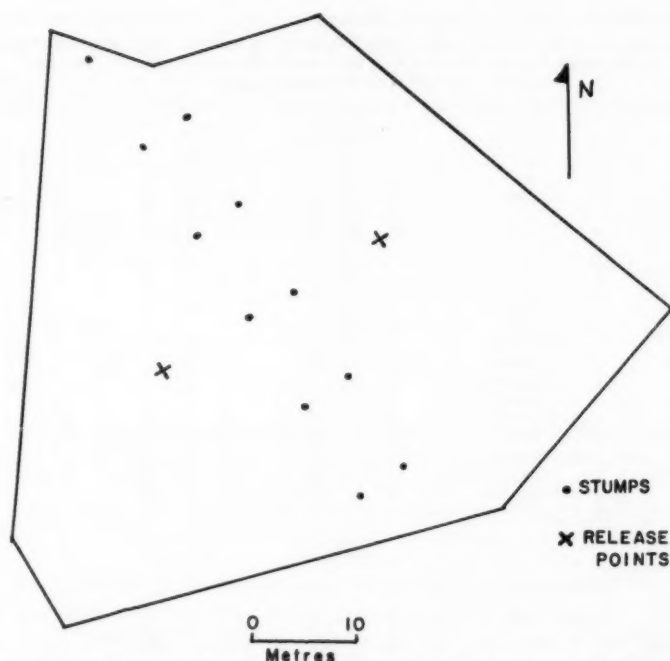
Fig. 1. Shape of the study area near Kamloops showing the two rows of stumps (marked as dots) dividing the area into two zones, and the two release points (marked as crosses).

zone in which they were collected. (Fig. 1). By repeated marking, release, and recapture the amount of movement between the two zones could be measured.

As the population was too low for catches to be made by general sweeping, specimens were collected singly. Two collectors each worked for one hour a day in each zone. After collecting, marking, and releasing for three successive days the area was left undisturbed for seven days and the experiment then continued for a further two successive days.

Results

Table I shows the numbers of marked adults recaptured at various dates and also indicates whether they were recovered in the same or opposite zone from which they were released. Of the 286 males and 409 females marked and released a total of 103 males (36.0%) and 169 females (41.3%) were recaptured. Only 3 males (1.0%) and 7 females (1.7%) were found in the opposite zone. As the distance from the release point in one zone to the boundary of the opposite zone was only 15 metres it is obvious that there was very little movement within the population. The data are therefore not suitable for more detailed analysis of such factors as population numbers, death rates, etc. but visual estimates showed that the population declined from 1.0 per square yard, with a nymphal population of 15 per cent on August 7th, to 0.75 per square yard with a nymphal population of two per cent on August 17th.

Discussion

Marked grasshoppers were just as active and just as hard to capture as unmarked ones. The possibility that the lack of movement was due to the immobilizing effect of the paint can therefore be ruled out.

TABLE I

Recapture of marked *M. bilituratus* adults showing whether they were recovered in the same zone as that in which they were released or whether they had moved into the opposite zone

MALES

Date	Aug.	7	8	9	16	17	Totals
Captured		61	75	87	74	80	377
Released		61	66	86	73	0	286
Recaptured Date Aug.	Zone						
8	Same	6	—	—	—	—	6
	Opposite	0	—	—	—	—	0
9	Same	3	19	—	—	—	22
	Opposite	0	1	—	—	—	1
16	Same	1	6	3	—	—	10
	Opposite	0	1	0	—	—	1
17	Same	1	16	10	35	—	62
	Opposite	0	1	0	0	—	1
Total	Same	11	41	13	35	—	100
	Opposite	0	3	0	0	—	3

FEMALES

Date	Aug.	7	8	9	16	17	Totals
Captured		88	118	110	104	126	546
Released		88	107	110	104	0	409
Recaptured Date Aug.	Zone						
8	Same	12	—	—	—	—	12
	Opposite	0	—	—	—	—	0
9	Same	6	28	—	—	—	34
	Opposite	0	3	—	—	—	3
16	Same	1	10	9	—	—	20
	Opposite	0	1	0	—	—	1
17	Same	4	17	20	55	—	96
	Opposite	0	1	2	0	—	3
Total	Same	23	55	29	55	—	162
	Opposite	0	5	2	0	—	7

Riegert *et al.* (1954) found that fifth-instar nymphs and adults of *M. mexicanus* (*M. bilituratus*) tagged with P[32] moved more than 140 yards in seven days over bare ground, but Baldwin *et al.* (1958) found that they moved less than 40 yards in 18 days when vegetation was present and that the majority of them were concentrated within 20 yards of the release point. Moreover the authors point out that the release of several thousand grasshoppers at a single point might be expected to promote dispersal. In the present work specimens were released individually as they were marked so that approximately 100 were released from each point over a period of one hour. The disturbance resulting from an abnormal increase of the natural population was therefore kept to a minimum.

Parker (1930) found that an air temperature of 66°F was the lower threshhold of activity of *M. mexicanus* under field conditions and that when they were present in large numbers flight activity began if an air temperature of 84°F was combined with a light breeze. The weather data for Kamloops during the

period of the experiment as given in the Department of Transport Daily Weather Map were as follows:-

Date	Temperature		Wind	
Aug.	Max.	Min.	velocity	Precipitation
7	90	55	0	0
8	93	57	6	0
9	97	63	4	0
10	101	60	0	0
11	100	58	16	0
12	92	64	4	0
13	—	—	—	—
14	74	51	14	0.06
15	80	60	2	Trace
16	82	58	3	0.04
17	86	62	0	0

Even with a low population density it might be expected that these climatic conditions would be conducive to high activity and the relative immobility of the population during this period is therefore rather surprising.

Many factors such as age, food supply, population density, and temperature will influence the extent to which movement takes place in a grasshopper population, but if for any reason the marked specimens do not mix thoroughly with the wild population then the method of estimating populations by marking, release, and recapture becomes invalid. It is possible that this defect could be overcome by releasing marked specimens from a number of different points rather than from one single point, but it is obvious that care should be exercised when using the Lincoln Index as a means of estimating *M. bilituratus* populations.

Summary

By the technique of marking, release, and recapture it was shown that very little movement of adult *M. bilituratus* (Walker) occurred during a ten-day period of hot dry weather at Kamloops, B.C. and under the conditions of the experiment the Lincoln Index would not have given a valid estimate of the density of the population.

Acknowledgement

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The Genus *Bolbomyia* Loew (Diptera : Rhagionidae)

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The genus *Bolbomyia* Loew, 1850, was erected on the basis of specimens in Austrian amber. No specific name was applied to the material. *Bolbomyia nana* Loew was described in 1862 from a single female collected at Washington, D.C., U.S.A. The species has since been redescribed twice, as *Misgomyia obscura* by Coquillett, and as *Ptiolina mitis* by Curran, on the basis of eastern North American material.

A second species has recently been collected in western North America, and it is the purpose of this paper to describe this new species and redescribe the genus.

The species of *Bolbomyia* occur in early spring and the males are usually found resting on the leaves of shrubbery, whereas the females are frequently collected from flowers. They are extremely small for rhagionids (only two to three mm. in body length), dull black with infuscated wings, and may be easily recognized by the typical rhagionid venation, a single apical spur on the fore tibia, and by the many long hairs on the antennae. Further, but much less obvious, characters are the hairy face and distinctly two-jointed style of the antennae.

The correct assignment of this rather primitive genus is difficult. The combination of the two-jointed style, tibial spurs on all three legs (1-2-2), primitive wing venation and genitalia, and pulvilliform tarsal empodium does not fit any of the present subfamilies of Rhagionidae. In general appearance, it is closest to *Ptiolina* Zetterstedt, from which it differs only in having the two-jointed style and the apical spur on the fore tibia. It differs from *Spania* Meigen and *Hilarimorpha* Schiner in having the typical rhagionid bristling of wing vein R_1 (second vein). It resembles *Hilarimorpha* alone in having the two-jointed antennal style, but that genus lacks tibial spurs, pulvilliform empodium, and the discal cell is open. Both *Bolbomyia* and *Hilarimorpha* appear to represent early divergences from the main Rhagionid evolutionary line, and should be set off as separate subfamilies or at least as tribes of the subfamily Rhagioninae.

Bolbomyia Loew

Bolbomyia Loew, 1850, Ueber Bernstein und die Bernstein-fauna, p. 39; Loew, 1862, Berl. Ent. Zeit. 6: 188; Leonard, 1930, Mem. American Ent. Soc. 7: 74. Type species: *Bolbomyia nana* Loew, 1862.

Misgomyia Coquillett, 1907, Proc. Ent. Soc. Washington 9: 145. Type species: *Misgomyia obscura* Coquillett, 1907 (=*Bolbomyia nana* Loew).

Male

Head.—(Fig. 2) Hemispherical, ocellar triangle prominent. Eye large, faintly sinuate on posterior margin, almost obscuring frontal area, not incised at antennae; facets unequal, distinctly smaller below than above antennal base. Face narrow, usually almost hidden by the bulging eyes, parafacials bearing eight to ten bristles on each side. Occipital surface densely and rather uniformly bristled.

Antenna (Figs. 4-6) with first segment usually hidden between the eyes, weakly and sparsely bristled; second segment subglobose with two irregular rings of bristles which are longest dorsally; third segment ovate to elongate conical, bearing from four to twenty bristles which are usually concentrated on dorsal and

Figs. 1-3, 6-8. *Bolbomyia macgillisi* n. sp. Figs. 5, 6. *B. nana* Loew. 1. Left wing, dorsal. 2. Head, male, lateral. 3. Head, female, lateral. 4-6. Right antenna, male, lateral. 7-8. Male hypopygium; 7, ventral; 8, dorsal.
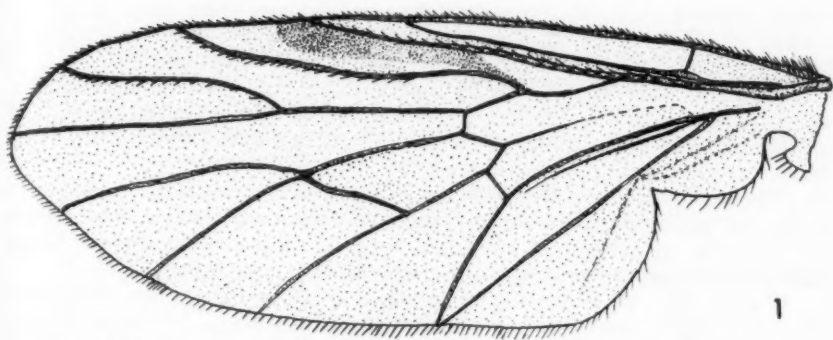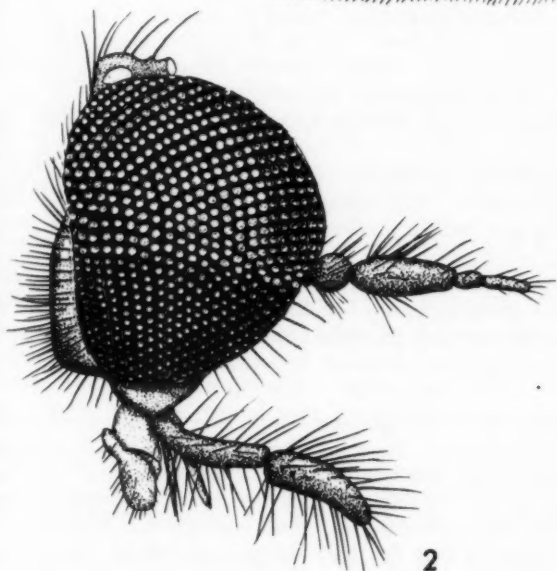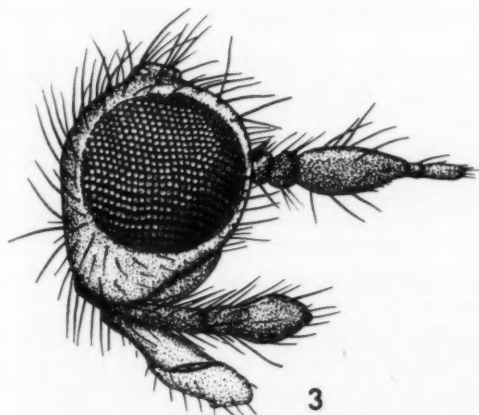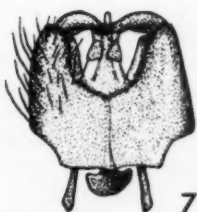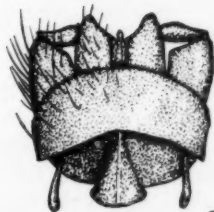
ventral surfaces; style two-segmented, the basal segment short, with or without a dorsal bristle, the apical segment elongate, twice the length of the basal segment, with a tuft of short apical hairs and one to five bristle-like hairs basad.

Proboscis with well developed mouth parts, theca largely membranous. Palpus with two densely-bristled subequal segments, basal segments slender and cylindrical, apical segment elongate conical, length of palpus slightly greater than distance from its base to base of antenna.

Thorax.—Integument brownish-black covered with uniform dark brown pollinosity, not vittate. Propleuron densely bristled around spiracle, other pleural surfaces bare. Notal bristles numerous, irregular, dorsocentrals slightly longer than others. Scutellum with two to three rows of irregular bristles.

Wing.—(Fig. 1) Venation and outline normal for the family. Membrane infuscated, stigma slightly darker, not strongly differentiated. R_1 densely bristled above except basad of the humeral crossvein. Apical two-thirds of R_{2+3} and R_4 bristled beneath or bare. Other veins bare. M_1 and M_2 forking at medial crossvein or a short distance basad or apicad. Medial crossvein often distinctly sinuate. Cubital (anal) cell closed or slightly open at wing margin.

Haltere dark brown, stem shorter than elongate knob. Squama small and weakly haired.

*Legs.*—Dark brown pollinose, structure and bristling unspecialized. No distinctly stronger rows of bristles. Both tibial spurs present on mid and hind legs, only the posteroventral spur present on the fore leg. Hind coxa not bristled behind.

Abdomen.—Dark brown pollinose, usually obscuring the subshining integument. Bristling general, the apical segmental bristles not distinctly stronger. Tip of abdomen distinctly curved upward, genitalia inconspicuous and very simple in structure (Figs. 7, 8).

Female

Head.—(Fig. 3) Height two-thirds greatest width, one and one-third times length. Cheek two-fifths eye height. Frontal width at antennae equal to width of one eye, frons widening to one and one-fifth eye width at level of anterior ocellus. Frontal bristling sparse and short except for distinct orbital bristles. Eye circular in outline in profile, facets uniform. Face strongly broadened below antennae, bare; parafacial bristling as in the male except for a tuft of four to five hairlike bristles opposite antennal base.

Antenna as described for the male, but bristling sparser, and second segment of style slightly shorter.

Proboscis as in the male, except palpus slightly shorter, the apical segment spatulate, broadened and swollen beyond the middle, then tapering to an acute apex, bristling sparse on apical half.

Thorax, Wing, and *Legs.*—As described for the male, except that the bristling is generally shorter and weaker.

Abdomen.—Simple in structure, tapering evenly to a short ovipositor with small quadrate cerci.

Bolbomyia macgillisi, new species
Figs. 1, 2, 3, 4, 7, 8

This western species can be easily separated from the eastern *B. nana* by the bristles on veins R_{2+3} and R_4, the elongate and densely bristled third antennal segment, and by the darker, more glossy thorax and abdomen. Length (exclusive of antennae) male, 2.8-3.2 mm. (mean of 10 specimens, 2.75 mm.).

Head.—Antenna with third segment three times as long as wide, bearing from ten to twenty bristles in the male (Figs. 2, 3) and from eight to fifteen bristles in the female; basal segment of style with a distinct dorsal bristle, apical segment usually with two to five bristles in addition to the apical ones.

Thorax.—Subshining brownish-black, with patches of denser brownish pollen on notum which do not form distinct vittae

Wing.—Apical two-thirds of vein R_{2+3} with a row of about 20 setulae on ventral surface. Vein R_4 with a row of about 15 setulae extending to fork of R_{4+5} on ventral surface.

Abdomen.—Subshining brownish-black, the pollinosity faint. Male genitalia as in Fig. 7.

Types

Holotype.— ♂, Kitsumkalum Lake, 20 mi. N. of Terrace, British Columbia, 31.V.1960 (J. G. Chillcott).

Allotype.— ♀, same data.

Paratypes.—47 ♂ ♂, 28 ♀ ♀ all from British Columbia, as follows: 15 ♂ ♂, 5 ♀ ♀, same data as holotype; 2 ♂ ♂, 12 ♀ ♀, same date and locality (W. W. Moss); 11 ♂ ♂, 4 ♀ ♀, same data and locality (G. E. Shewell); 5 ♀ ♀, same data and locality (C. H. Mann); 15 ♂ ♂, Cameron Lake, 4.VI.1955 (J. R. McGillis); 2 ♂ ♂, Horne Lake, 4.VI.1955 (R. Coyles); 1 ♂, Bowser, 30.V.1955; 1 ♂, Cowichan Lake, 25.IV.1941 (M. L. Prebble); 2 ♀ ♀, Kleanza Creek, nr. Terrace, 17.VI.1960 (C. H. Mann).

Remarks

The type series was collected in an open lakeshore clearing in dense coastal forest, the males with males of *Iteaphila orchestris* Melander on leaves of high shrubs, the females on flowers of *Rubus* and *Taraxacum*. On a return trip to the locality less than a week later, the species was not found.

Bolbomyia nana Loew
Figs. 5, 6

Bolbomyia nana Loew, 1862, Berl. Ent. Zeit. 6: 188; Leonard, 1930, Mem. American Ent. Soc. 7: 74.

Misgomyia obscura Coquillett, 1907, Proc. Ent. Soc. Washington 9: 145, syn. *teste* Leonard, 1930.

Ptiolina mitis Curran, 1931, Canadian Ent. 63: 249; Hardy and McGuire, 1947, Journ. Kansas Ent. Soc. 20: 9. New synonymy.

This species can be separated from *B. macgillisi* by the bare veins R_{2+3} and R_4, the shorter and less bristled third antennal segment, and the brown pollinose thorax and abdomen. Length (exclusive of antennae): male, 2.1-3.2 mm. (mean of 7 specimens 2.8 mm.); female (one specimen) 2.6 mm.

Head.—Antenna with third segment twice as long as wide, bearing from four to eight bristles on the male, and one to three bristles in the female; basal segment of style with one or usually no dorsal bristle, apical segment usually with only a single bristle in addition to the apical ones.

Thorax.—Dull brown pollinose, occasionally subshining of pleura, without distinct irregular pollinose patches on the notum.

Wing.—Vein R_{2+3} and vein R_4 with no setulae on ventral surface.

Abdomen.—Dull brown pollinose, occasionally subshining in the female.

Type locality and *type*

B. *nana*—Washington, D.C. Type in Museum of Comparative Zoology, Harvard University, Cambridge, Mass.

M. *obscura*—opposite Plummer's Island, Virginia. Type in U.S. National Museum, No. 1150.

P. *mitis*—Natashquan, Quebec. Type in Canadian National Collection No. 3416.

Records 19 ♂ ♂, 6 ♀ ♀, as follows

NEW HAMPSHIRE. White Mountains, 1 ♀. NEW YORK. Golden, 3 ♂ ♂; North Evans, 2 ♂ ♂; Danby, 4 ♂ ♂, 1 ♀. PENNSYLVANIA. No locality, 1 ♂. MARYLAND. Forest Glen, 1 ♂. VIRGINIA. Opposite Plummer's Island, 1 ♀. DISTRICT OF COLUMBIA. Washington, 1 ♀. MICHIGAN. Battle Creek, 1 ♂. NOVA SCOTIA. Annapolis, 1 ♂. QUEBEC. Knob Lake, 4 ♂ ♂, 1 ♀; Old Chelsea, 1 ♂; Natashquan, 1 ♂.

Collecting dates April 28 to July 19 (April 28 to May 30 south of Quebec).

Summary

Bolbomyia macgillisi, new species, is described from British Columbia. It is distinguished from B. *nana* Loew by the ventrally-setulose radial veins and elongate third antennal segment. The genus *Bolbomyia* is redescribed and illustrated. *Ptiolina mitis* Curran is synonymized with B. *nana*.

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Movement on the Soil Surface, of Adult *Ctenicera aeripennis destructor* (Brown) and *Hypolithus bicolor* Esch. (Coleoptera: Elateridae), as Indicated by Funnel Pitfall Traps, with Notes on Captures of other Arthropods[1]

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The two most important economic species of Elateridae in Saskatchewan are *Ctenicera aeripennis destructor* (Brown) and *Hypolithus bicolor* Esch. Adults of both species have been observed moving on the soil surface, but the extent and the seasonal duration of this movement has never been fully investigated.

The activity of several species of wireworm adults has been studied by trapping with baits, or by collection from underneath various types of cover where they seek refuge (Hawkins 1936, Campbell and Stone 1939 and Cohen 1942). This type of trap however, gives no assurance that the beetles will stay under the refuge for any definite period, and does not permit a quantitative estimate of the population.

Fig. 1. A funnel pitfall trap used to study the movement of adult Elateridae on the soil surface. A, the funnel with catch can and the gallon can buried in the soil; B, the trap in position in the gallon can.

A funnel pitfall trap was used for preliminary studies of the movement of *C. a. destructor* and *H. bicolor* at Saskatoon in 1959 and 1960.

Methods

The trap consisted of a stainless steel funnel with a catch can attached to the bottom (Fig. 1). The diameter of the funnel and the catch can were 6¾ and 4 inches respectively. The total depth of the trap from the rim of the funnel to the bottom of the catch can was 7⅞ inches. A horizontal flange ½ inch wide, on the rim of the funnel, rested on the rim of a gallon can, buried in the soil, level with the soil surface (Fig. 1). The horizontal flange extended in toward the centre of the funnel ⅛ inch, forming an abrupt overhang. Once beetles ran over

the edge of the flange, they always fell directly into the funnel and slipped into the catch can.   Rain water drained through a fine stainless steel screen soldered to the bottom of the catch can and then into the soil through holes drilled in the bottom of the gallon can.   Once the trap was in place it could be checked with very little effort and without disturbing the surrounding soil.

The study area, a section of a continuously cropped wheat field at the University of Saskatchewan, was divided into 3 plots each 72 x 26 yards.   On April 13 in 1959, and April 19 in 1960, four traps were placed in each of the plots, 18 yards from the ends and 8 yards from the sides of plots.   The distance between traps in adjacent plots was not less than 16 yards.

Traps were checked daily at approximately the same time, except during the latter part of the period of seasonal activity when only an occasional beetle was captured.   On several occasions during both seasons rainy or very cool weather prevented trap checks, but observations at the end of such unfavourable weather periods showed that no captures had occurred.   No collection was made May 28, 1959 when traps were removed while the field was being cultivated and seeded to wheat.   In 1960 traps were left in place while the field was cultivated.

The sex of each beetle captured was determined by examination under a binocular microscope.   Females were dissected to determine numbers and development of eggs.   None of the beetles were released in the study area after being captured.

During the period of beetle activity, continuous records were obtained of the soil temperature at 3 and 6 inch depths, and in addition at ½ inch and 1 inch depths in 1960.

The data on daily beetle captures were transformed using a $\sqrt{x} + 1$ transformation where x represents the original value.   The "t" test was used to determine whether the mean number of adults per plot differed significantly.   Each sex of each species was compared separately.

Results and Discussion

C. aeripennis destructor

During 1959, a total of 2170 males were caught in 12 traps from April 14 to May 18, compared with 364 females from May 16 to June 26 (Fig. 2), a ratio of approximately 6:1.   Prior to placing the 12 traps in the study area on April 13, 40 males were captured in 10 traps in another section of the field, the first on April 6.

The numbers of males trapped per day, although subject to weather variations, increased to a peak on April 28.   After May 7, activity of males on the soil surface declined and relatively few were taken in traps.   The most females were captured between June 2 and June 6.   Only four females were trapped after June 26.

During 1960, 3864 males were trapped from April 20 to June 14, compared with 464 females from April 20 to July 13 (Fig. 3), a ratio of approximately 8:1.   The greatest number of males were trapped May 7, and after May 13 only small numbers were taken.   Although a few females were captured early in the season, they were not trapped regularly until May 26.   The majority of females were trapped between June 6 and June 15.   Small numbers were then captured until July 13, but none thereafter.

There were distinct differences in the trapping results for the two seasons.   Both the total number of adults, and the ratio of captured males to females was greater during 1960 than in 1959.   In addition females were trapped earlier, and males later in the season than in 1959.   In 1959 (Fig. 2) there was only a two-day

Fig. 2. Daily totals of *C. a. destructor* adults captured in funnel pitfall traps (bargraph), and mean hourly soil temperatures (8 a.m. to 8 p.m.) at the 3-inch depth (solid line), 1959.

overlap when both males and females were trapped, whereas in 1960, (Fig. 3) a few males were still being trapped in June, and 12 females were taken in traps during April and the early part of May. However females did not move on the soil surface to any extent until May 26.

The difference in the trapping results of the two seasons may have been due to a greater population of beetles during 1960, increasing the chances of capturing females earlier, and males later, in the season, than had been the case in 1959.

Males were strongly attracted to unmated females, and this desire for mating appeared to provide the greatest stimulus for male movement on the soil surface. On several occasions during April and May, males were observed converging on emergence cages[3]. If a single male were placed in such a cage, it would immediately seek out and mate with the female which was hidden in a crack just below the soil surface. Lilly (1959) reported that this same type of attraction with *Limonius californicus* (Mann.) was due to a female sex attractant. In the present study, even though females emerged from their overwintering cells to the soil surface during April and early May and mated, they did not move on the soil surface to any extent at this time, but remained in the soil for approximately three weeks and then became active on the soil surface and were trapped. Female movement on the soil surface is probably stimulated partly by desire for suitable oviposition sites and partly by food seeking behaviour, since food material was found in guts of dissected adults from traps.

[3]A wooden screen covered cage (18″ x 18″ x 6″) set on the soil surface to collect wireworm beetles that emerged from the soil under the cage.
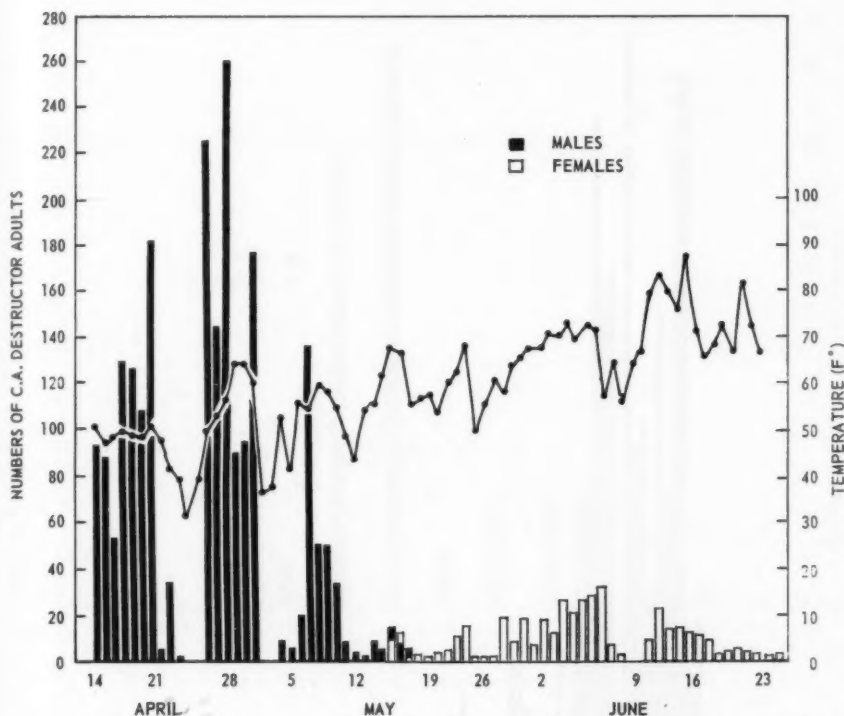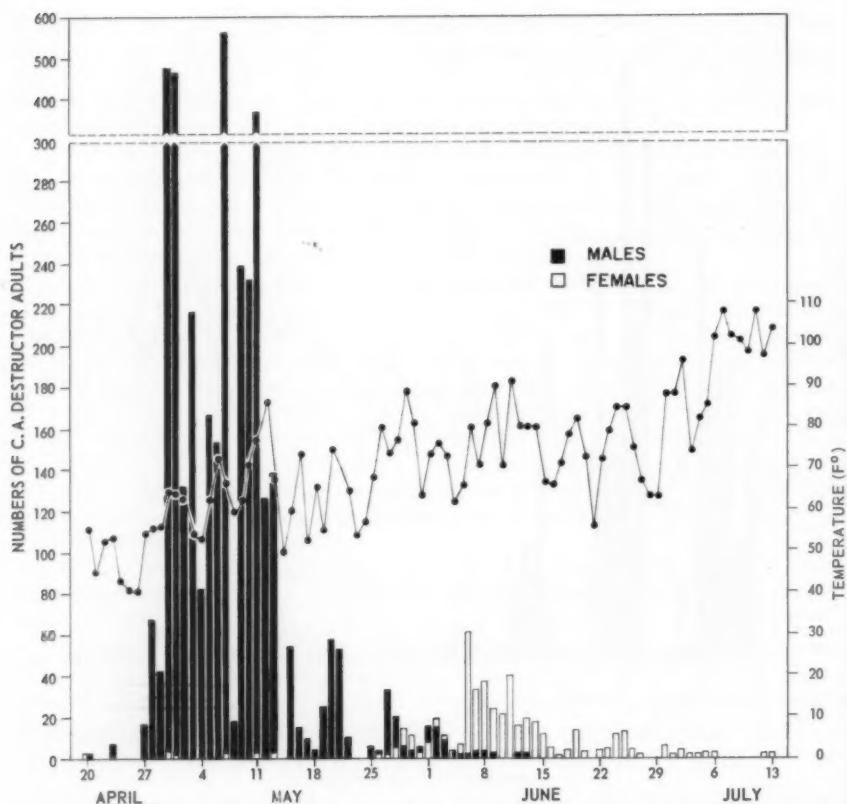
Fig. 3. Daily totals of *C. a. destructor* adults captured in funnel pitfall traps (bargraph), and mean hourly soil temperatures (8 a.m. to 8 p.m.) at the ½-inch depth (solid line), 1960. A split bar was used if the same number of each sex were trapped (1 male and 1 female on April 20, and 2 males and 2 females on June 4).

Cool or cool rainy weather restricted the movement of both sexes on the soil surface. During 1959 a comparatively small number of males were trapped when the mean soil temperature fell below 45°F. at the 3 inch depth (Fig. 2). This occurred from April 21 to April 25, and from May 2 to May 5. Similarly movement of females decreased on days when the mean temperature of the soil fell below 60°F., and few beetles were trapped. Only two were trapped between June 8 and June 11, when a period of cloudy rainy weather prevailed.

Cool cloudy weather restricted adult movement during April in 1960, and few captures were made. However with the advent of favourable temperatures in May, large numbers of males were taken. On several occasions during May periods of cloudy rainy weather accompanied by some decrease in temperature, restricted movement of males and few were trapped. This was evident (Fig. 3) on May 8, May 14, May 16 to 18, and May 22 to 24. Similar weather conditions on June 4 and 5, June 16 to 18, June 21 and June 27 to 29, resulted in few or no captures of females.

Dissections made in 1959 revealed that females were carrying the most eggs between May 16 and May 23. A sudden decline in average numbers of eggs per
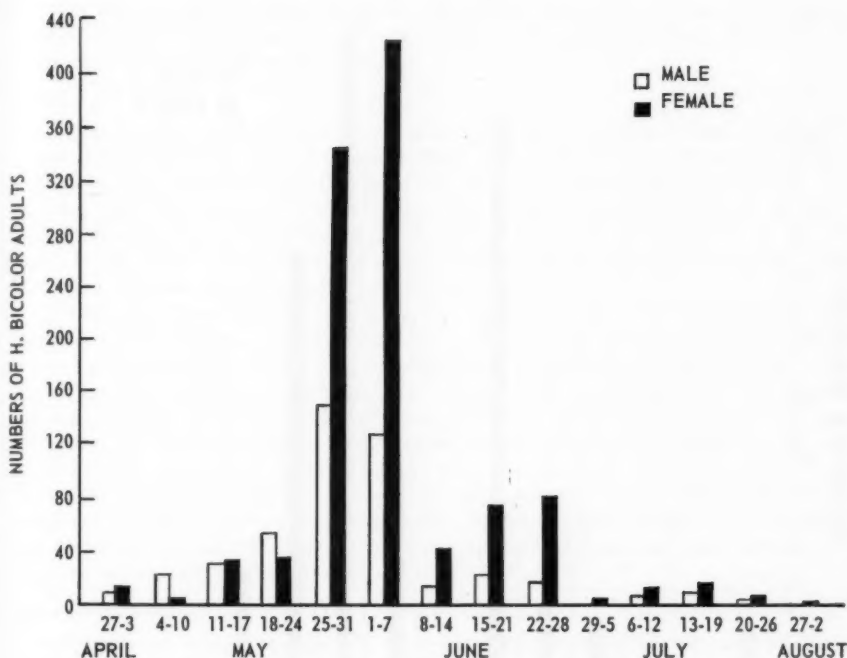
Fig. 4. Weekly totals of *H. bicolor* adults captured in funnel pitfall traps, 1959.

female was evident from May 23 to June 2, suggesting that the most active period of oviposition preceded the period of maximum movement. Females moved about on the soil surface, indicating that eggs were not all oviposited in one place. Some oocyte production was evident in females collected at the end of June and in July.

There was no significant difference between the means of the total numbers of beetles caught in the three plots for either sex during either season. This indicated a uniform distribution of *C. a. destructor* adults throughout the study area.

H. bicolor

The pattern of activity of *H. bicolor* differed from that of *C. a. destructor*. During both seasons both sexes were active on the soil surface over approximately the same period. In 1959 both sexes started to move on the soil surface the same day, April 27. Males were taken in traps until July 24, females until July 30. Fewer males (453) were captured than females (1088), a ratio of approximately 1:2 (Fig. 4). In 1960 the first *H. bicolor* adults, two females, were trapped May 6, and a male and a female were trapped May 9 (Fig. 5). The last male was trapped August 7, and the last female August 14. As in the previous season fewer males (228) were captured than females (524), again a ratio of approximately 1:2. However the total number of adults captured was less than the previous season.

During 1959 there was a very pronounced increase in surface movement on May 29 (Fig. 4), the day after the field was cultivated and sown. On May 30, 136 females were taken in the 12 traps, the greatest number trapped on any one
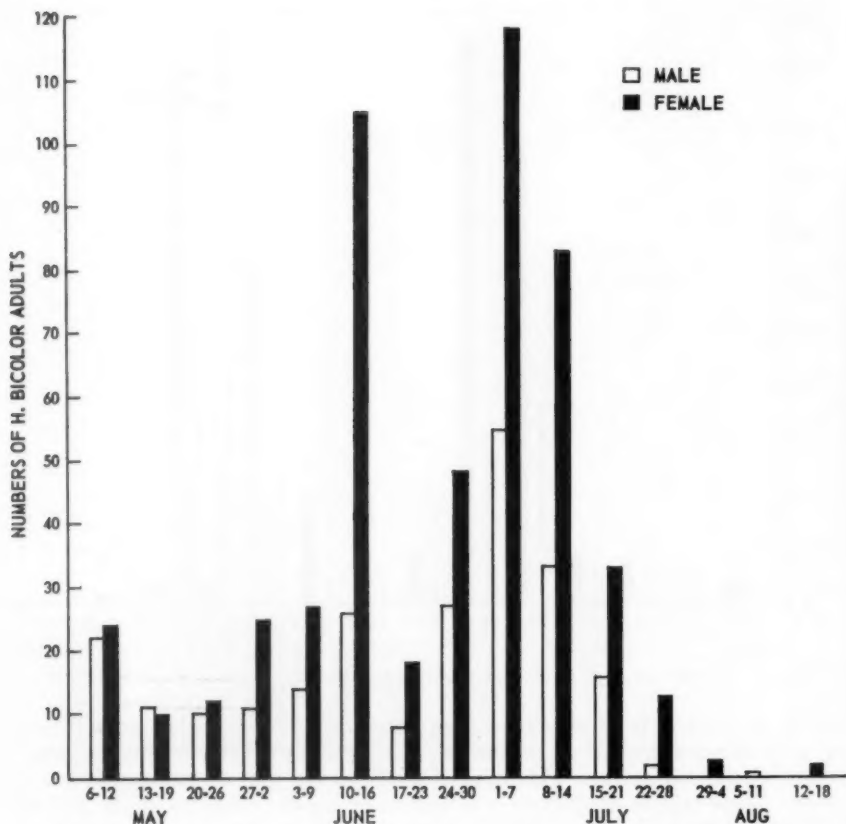
Fig. 5. Weekly totals of *H. bicolor* adults captured in funnel pitfall traps, 1960.

day. This high degree of activity, mostly restricted to plot 2, was evident for less than a week, and then declined sharply to continue at a much reduced rate till the end of July. Although fewer beetles were trapped during 1960 two peaks were nevertheless evident (Fig. 5), from June 10 to 16 and from July 1 to 14. The decrease in numbers trapped from June 17 to June 30 was the result of several days of cloudy rainy weather which occurred from June 16 to 18 and from June 27 to 29.

The exact reason for the sudden increase in beetle activity on May 29 in 1959, is not known. Originally this was thought to be due to increased soil temperatures following cultivation. However cultivation appeared to have little effect during 1960, since approximately the same numbers of beetles were trapped in plots which were cultivated and uncultivated.

There was a highly significant difference between the mean numbers of males trapped in plot 1, and plots 2 and 3 in 1959. The means of plot 2 and plot 3 however did not differ significantly. The same situation existed with the females in regard to statistical differences except that the means of plot 1 and plot 2 were significantly different at only the 5 per cent level. The differences between means in the three plots indicated that the adult population of *H. bicolor* was not as evenly distributed throughout the field as that of *C. a. destructor*.

In 1960 both sexes were trapped to about the same extent in the three plots and no differences in the means were evident indicating that there was a more even distribution of the population.

Larvae

Larvae of *C. a. destructor* were taken in traps on several occasions in 1959 indicating that under some conditions there was movement of the larvae of this species on the soil surface. On June 12, 45 larvae were taken in 12 traps, the number per trap varying from 0 to 13. No larvae were taken in traps in July, but small numbers were collected on the following dates: August 4, 6, 7, 10, 13 and 18. In 1960 a total of only 6 larvae were taken in traps, one each on May 2, July 3, August 9 and August 31, and 2 on August 1.

The conditions which induce larval activity on the soil surface are not known. Temperature and moisture are probably the most important factors since the greatest movement in 1959 took place in June after a heavy rain. No more captures were made until August. The soil temperatures were the highest of the season during July, and may have prevented larval movement on the surface, which was then resumed in August when soil temperatures began to decline. In 1960 the number of larvae trapped was too small to gain inference from weather conditions. All the larvae were approximately in the same size range, medium to large. This suggests that larvae reach some physiological state in their development which stimulates movement toward and on the soil surface, if climatic conditions are favourable.

Other Arthropods

Cutworms, mainly red-backed, were caught in considerable numbers in May and the early part of June particularly in 1959. A continuous record of cutworms in traps was not kept, but the following numbers were trapped on the dates indicated: May 24, 14; May 25, 3; May 29, 9; May 31, 116; June 1, 32; June 3, 42. The number taken per trap was not uniform indicating that there were concentrations of cutworms in some sections of the field.

The following orders and families were also taken in pitfall traps. Class Insecta: Order Orthoptera; Tettigoniidae (camelback crickets) and Acrididae (both nymphs and adults). Hymenoptera; Ichneumonidae and Formicidae. Coleoptera; Carabidae (larvae and adults), Tenebrionidae (larvae and adults), Silphidae, Chrysomelidae, Curculionidae, Cicindelidae and Scarabaeidae. Class Arachnoidea: spiders and mites.

Although the results presented here are of a preliminary nature, it appears that the funnel pitfall trap will be a useful device for studying the activity of adult Elateridae on the soil surface. In addition the general observations on collections of other insects indicate that the trap might be successfully used as a sampling and collecting device. It may prove particularly useful in ecological studies of insects which move at night and which otherwise would not be observed.

Summary

A pitfall trap used to study the activity of adult *Ctenicera aeripennis destructor* (Brown) and *Hypolithus bicolor* Esch. (Coleoptera: Elateridae) is described.

The greatest movement of male *C. a. destructor* on the soil surface took place in the latter part of April and the first part of May. Females were most active on the soil surface during the last part of May and the first part of June. In 1959, males were captured in traps from April 6 to May 18, while females were captured

from May 16 until July 17. A total of 2210 male and 368 female beetles were trapped, a ratio of approximately 6:1. In 1960, 3864 males were trapped from April 20 to June 14, compared with 464 females from April 20 to July 13, a ratio of approximately 8:1. Although a few females were trapped in the first part of the season they were not captured consistently until May 26.

The two sexes of *H. bicolor* were active on the soil surface over almost the same period. In 1959 males were collected from traps from April 27 until July 24, females until July 30. A total of 453 males and 1088 females were trapped, a ratio of approximately 1:2. In 1960 males were collected from traps from May 6 until August 7, females from May 6 until August 14. The total number of *H. bicolor* trapped was less than the previous season, 228 males and 524 females, again a ratio of 1:2.

Larvae of *C. a. destructor* were also taken in the traps indicating that larvae of this species move on the soil surface under favourable conditions.

Considerable numbers of cutworms and other insects were taken in traps throughout the summer suggesting that this type of trap could be used as a general sampling device.

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(Received January 11, 1961)

The Eriophyid Mite *Aceria tulipae* (K.)
(Acarina: Eriophyidae) and Silver Top in Grasses[1]

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Sterility of grasses caused by a constricted brown region, usually in the upper internode, is commonly described as silver top because of the bleached appearance of the inflorescence. Hodgkiss (1908) reported that silver top was caused by the mite, *Siteroptes graminum* (Reuter), in conjunction with the fungus, *Fusarium poae* (Pk.) Wr. Brown *et al.* (1952) found that in the greenhouse several chlorinated hydrocarbons controlled *S. graminum*. Hardison *et al.* (1957) reported that *S. graminum* in combination with *F. poae* was of little importance in causing silver top of cultivated grasses in western Oregon. They suggested that two thrips of the genus *Aptinothrips* might be the primary cause. They recommended DDT or heptachlor applied in late April or early May. They also found that post-harvest burning reduced silver top.

Silver top has affected some acreages of Merion bluegrass, *Poa pratensis* L., in Alberta. In early June 1957, affected stems from a field of this grass were examined and eriophyid mites were found in the necrotic regions of the internodes. As a result work was started to determine if these mites were generally present on stems with silver top.

TABLE I

Numbers of stems of various grass species examined for mites and insects

Date	Location	Species of grass	Number of healthy stems	Number of stems with silver top
June 3, 1958	Bow Island	*Poa pratensis* (Merion blue)	15	85
May 31, 1960	Bow Island	*Poa pratensis* (Merion blue)	50	0
June 9, 1960	Scandia	*Poa secunda*	56	58
June 9, 1960	Scandia	*Koeleria cristata*	20	22
June 10, 1960	Spring Coulee	*Poa pratensis*	25	25
June 10, 1960	Fort Macleod	*Poa pratensis*	25	25
June 10, 1960	Claresholm	*Poa pratensis*	25	25

Methods and Materials

Random samples of stems were obtained from various locations within an 80-mile radius of Lethbridge in 1958 and 1960. Details of the collections are given in Table I.

Observations of these stems were made by slitting the leaf sheaths to expose the internodes, then examining the exposed internodes and the inside of the leaf sheaths under magnification. In addition, large areas of a field of Merion bluegrass at Bow Island, Alberta, were burnt in the fall of 1957. In 1959, pieces of wheat leaves bearing large numbers of *Aceria tulipae* (K.) were placed on four plots of Merion bluegrass under mite-proof cages. Four uninfested check plots were also caged. Examinations were made on July 7.

Results and Discussion

Examination under magnification showed no evidence of penetration through the leaf sheath. The causal organism must have attacked the stem from inside the sheath. The constricted brown region occurred in either the top or the penultimate internode, and occasionally in both. This region is usually just above the node. Fungus was found in these areas in only a few affected stems, and in these cases was almost always associated with *S. graminum*.

Table II shows that thrips, *Limothrips cerealium* Hal. or *denticornis* Hal., and two species of mites, *Aceria tulipae* and *S. graminum*, were associated with silver top. These organisms were all found in the stem or on the inside of the leaf sheath. Silver top does occur in the absence of thrips and, with one exception, only relatively low infestations of thrips occurred.

In the 1959 test involving the transfer of *A. tulipae* to Merion bluegrass, although 79 per cent of the stems were infested with wingless thrips under the leaf sheath of the top internode, the only stem that was affected by silver top was infested with fungus and *S. graminum*. Although it is likely that the feeding by thrips in the meristematic region will cause silver top, these insects were generally of minor importance.

S. graminum was present in all samples of stems affected by silver top, and generally twice as frequently on stems affected by silver top as on the healthy stems. The necrotic areas were seldom infected with fungus; the percentages of stems that were infected varied from 0 to 10 per cent. *S. graminum* was usually found on these infected stems. It is apparent that *S. graminum* can produce silver top without the action of a fungus.

A. tulipae (Table II) was found to be generally present in *P. pratensis* and *P. secunda* in southern Alberta. June grass, *K. cristata*, was apparently not a

TABLE II

Infestations of grasses by two species of mites and by thrips at various locations
in Alberta in 1960

| Host | Location | Percentages of stems infested with | | | | | |
| | | A. tulipae | | S. graminum | | Thrips | |
		Healthy	Silver top	Healthy	Silver top	Healthy	Silver top
Merion bluegrass	Bow Island*	0	27	64	41	0	0
(*Poa pratensis*)	Bow Island	3	–	1	–	2	–
Kentucky bluegrass	Spring Coulee	4	16	4	8	56	72
(*Poa pratensis*)	Fort Macleod	0	56	6	31	6	13
	Claresholm	32	68	8	16	16	12
Poa secunda	Scandia	19	31	0	35	0	6
Koeleria cristata	Scandia	0	0	30	59	0	0

*Observed in 1958.

suitable host. Frequently *A. tulipae* was the more dominant mite species, and, as with *S. graminum*, it occurred more frequently on the affected stems than on the normal stems. *A. tulipae* is only 0.2 mm. long and relatively inactive, and hence more easily missed than either *S. graminum* or thrips. Therefore, the numbers of stems infested with *A. tulipae* are likely to be higher than reported here.

Generally only one species of mite was found on each stem, and usually at the necrotic region of the internode under the leaf sheath. Eggs of both mites were frequently found on the stems and leaf sheaths. *S. graminum* was usually present in numbers up to 20 per internode while the maximum number of *A. tulipae* was eight per internode. In 1958, the necrotic regions generally occurred in the top internode while in 1960 the penultimate internode was most frequently affected.

Environmental conditions are apparently very important in the incidence of silver top. Over 50 per cent of the stems of the Merion bluegrass at Bow Island were affected by silver top in 1957 and 1958. Silver top could not be found in the same field in 1959 and 1960. Wild species of *Poa* nearby that had silver top in 1958 did not have it in 1959 or 1960. It is very significant that the infestations of both *A. tulipae* and *S. graminum* in the bluegrass in the field at Bow Island fell from a high level in 1958 to a very low level in 1960.

A. tulipae from the *Poa* species is apparently a different strain from that which transmits wheat streak mosaic to wheat. Slykhuis (1955) could not rear *A. tulipae* collected from *Agropyron smithii*, *Hordeum jubatum*, and *Elymus canadensis* on wheat, nor could he rear *A. tulipae* from wheat on these grasses. Painter and Schesser (1954), however, successfully reared *A. tulipae* from *A. smithii* on wheat. In our test in 1959, none of the *A. tulipae* from wheat were found on the stems of Merion bluegrass.

Both mite species and thrips were found on unaffected stems, although usually less frequently than on the stems with silver top. These might have been newly established individuals that had migrated from affected stems. The damage occurs shortly after the top internode starts to elongate, as the affected heads are barely emerged from the leaf sheaths. Hence, it appears that necrosis will not occur unless the causal organism attacks the stem sufficiently early. More-

over, the feeding of only one mite of either species appears to be sufficient to cause silver top.

Eleven stems of crested wheat grass, *Agropyron cristatum* (L.) Gaertn. and 13 stems of awnless brome, *Bromus inermis* Leyss. collected near Lethbridge on June 24, 1960, were found to have silver top. The injury differed from that previously observed, in that it was limited to one side of the stem, occurred well above the node, and the internode had continued to elongate to form a coil in the sheath. Of the 11 *A. cristatum* stems, five were infested with thrips and one with *S. graminum* while seven of the 13 *B. inermis* stems were infested with thrips, and two were infested with *S. graminum*. Thrips were the major organism associated with injury in these two species of grass.

Fall burning gave good control of silver top. In the patches where most of the grass had been burnt, very few affected stems could be found, while in the unburnt areas over 80 per cent of the stems were affected.

Other causes of sterile white inflorescences in grasses occur. However, these are usually associated with visual symptoms on the outside of the leaf sheath. Russian wild rye, *Elymus juncius* Fisch., in the Lethbridge area is frequently damaged by an unknown insect that pierces the leaf sheath to feed on the stem. In a few stems of *P. secunda*, some insect had pierced the leaf sheath and deposited three or four eggs inside the internode, which was severed at that point.

Summary

A. tulipae was strongly implicated as a cause of silver top of *P. pratensis* and *P. secunda* at several locations in southern Alberta. *S. graminum* was equally implicated and was the only organism related to silver top in *K. cristata*. Fungus occurred in only a small proportion of the affected stems. Thrips were relatively unimportant.

Fall burning gave good control of silver top.

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(Received November 10, 1960)

Notes on the Biology of *Griselda radicana* (Wlshm.) (Lepidoptera: Olethreutidae)[1]

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Introduction

In the course of studies on different species of defoliators in field-spruce stands on the Gaspé coast of the Baie des Chaleurs, *Griselda radicana* (Wlshm.) occurred fairly commonly in such stands. Although the principal host tree of this insect is white spruce, *Picea glauca* (Moench) Voss, records of the Forest Insect and Disease Survey show that it has been collected from black spruce, *Picea mariana* (Mill.) BSP., Colorado spruce, *Picea pungens* Engelm., and balsam fir, *Abies balsamea* (L.) Mill. Although *G. radicana* is commonly found across Canada, there are no records that it has ever reached outbreak proportions. These investigations were undertaken since nothing was known on the life history and habits of this insect. The studies were carried out near New Richmond in the Gaspé Peninsula in the summer of 1959.

General Methods

Population density and insect development in the field were based on material obtained from full-length branches cut from the mid-crown of white spruce trees. One branch was cut from each of ten trees in each of four plots, at weekly intervals, from mid-May to mid-September. The same trees were used throughout the study. Since populations were calculated on a foliage-area basis, the length and width of the foliated portion of each branch was measured. The foliage from each branch was placed in numbered paper bags and brought to a field laboratory for careful examination. Some of the insects collected from the branches were kept for rearing while others were preserved in alcohol. These field collections provided information not only on *G. radicana* but on a number of other insect species that will be reported on elsewhere.

The plots were located in 40-year-old stands composed almost entirely of white spruce trees that had become established in abandoned fields. The trees averaged 30 feet in height and had foliage extending almost to the ground because of the open nature of the stands. Two of the stands were in New Richmond, one was at Nouvelle, 20 miles west, the other at New Carlisle, 30 miles east of New Richmond. Each stand covered several acres and the selected trees were assumed to represent conditions in the stands.

G. radicana proved to be a very difficult insect to rear in the laboratory. Nearly 75 per cent of the 814 larvae placed in rearing died. An attempt was made to rear the insects in groups of five in plastic vials. Although this method was very effective in the rearing of a number of other species of microlepidoptera feeding on white spruce, it was not suitable for *G. radicana*. Better results were obtained by rearing the insects in groups of 10 to 20 in 10-ounce glass jars equipped with finely perforated lids. Moist sphagnum moss was placed at the bottom of the jars and was re-moistened periodically as it dried out. This moisture kept the foliage fresh and obviated frequent changes of food. When the prepupal stage was reached the insects were left in an outdoor insectary where maximum temperatures reached between 80° and 85°F. Under these conditions mortality was high and was reduced only when the jars containing the insects were placed in a basement where temperatures varied little from 60°F. The reared material was used for the recovery of parasites and for obtaining some of

the adults used in oviposition experiments.   Insect development was based solely on field-recovered material.

Oviposition was studied by placing a number of newly-emerged males and females in lantern globes with white spruce twigs kept fresh by having the cut ends immersed in water.   Since there was a possibility that the insects might deposit their eggs on the bark, pieces of bark-covered wood from white spruce were also placed in the globes.

Life History and Habits

Adults

The first adults occurred in the field at the end of August and were seen until the end of the third week in September.   From a total of 176 adults obtained through rearing, 58 per cent were males and 42 per cent females.   Emergence of the males preceded that of the females by a few days.   On warm sunny days with low wind velocities, adults flew actively about the foliage of white spruce trees, often dropping to the ground and crawling over the vegetation. On dull days or after sunset the moths exhibited little activity.   Mating was not observed either in the field or in the oviposition cages.   In the cages, the first eggs were obtained from seven-day-old adults.   The adults, males and females, lived from two to three weeks in the cages.

Egg

The eggs are usually laid singly at the base of the needles.   They are oval-oblong in outline, appressed to the needles, and measure approximately 0.40 x 0.65 mm.   The surface of the egg is slightly pebbled.   Freshly laid eggs are pale green in colour, but change to a yellowish-orange after a few days.   The insect overwinters in the egg stage.

Larva

First- and second-instar larvae could not be differentiated in the spring from those of Zeiraphera ratzeburgiana Ratz. and Z. fortunana (Kft.) which occurred in considerable abundance in the study plots, but later in the season the more advanced Griselda and Zeiraphera larvae could be readily separated.   The time of eclosion of G. radicana larvae was determined from the collections and rearings that were made from the two Zeiraphera species.   The first field collections from which Zeiraphera were found were made during the last week in May but these collections did not produce any G. radicana.   However, the Zeiraphera rearings from collections made during the first week in June yielded a considerable number of G. radicana larvae.

Head-capsule measurements indicate that G. radicana has five larval instars (Fig. 1).   Measurements were obtained from larvae reared from eggs for the first two instars, and from field-collected larvae for the others.   Mean head widths were tested for goodness of fit with Dyar's (1890) rule of geometric growth; the comparison of observed and calculated widths is given in Table I. The per cent errors indicate that the observed values do not conform to Dyar's rule.   This may be explained by the constantly decreasing values of the intervals between successive stadia; for Dyar's rule to hold these should be approximtaely equal.   No further tests of goodness of fit were attempted.

The first-instar larvae average 0.85 mm. in length while the full-grown larvae average 9.1 mm.   The head-capsule and prothoracic shield is pale yellow for all larval instars except in the first instar which has a brown head capsule.   In young larvae, the body is pale yellow and shows no markings; in older larvae, the ground colour of the body is pale yellow and there are three indefinite
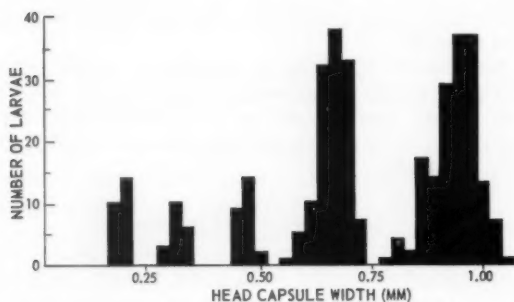
Fig. 1. *G. radicana* head-capsule widths derived from periodic preserved collections, New Richmond, 1959.

orange-brown longitudinal stripes, one dorsally and two laterally. In the cocoon the prepupae turn a pale cream colour and the stripes become indistinct.

The larvae fed on the current year's foliage for a period of six weeks and were often found in shoots damaged by other insects. Approximately 60 per cent of the fourth- and fifth-instar larvae were found in shoots damaged by *Zeiraphera* and a number also fed on galls formed by *Chermes abietis*.

The prepupae drop to the ground where they spin cocoons. In order to determine the time and rate of drop, two cloth trays each two feet wide and eight feet long were set beneath the crowns of each of two trees. The edges of the trays were covered with "tanglefoot" to prevent the larvae from escaping and to prevent predacious insects from carrying away the larvae. The trays were examined each day and the results are shown in Figure 2. The larvae dropped over a period of two weeks from July 7 to July 21 with close to 70 per cent of the drop taking place in the five-day period starting July 10. More larvae dropped on warm sunny days than on cool wet days. After dropping, the larvae burrowed immediately in the moss or humus. In the laboratory, spinning of the cocoons began one or two days after the larva had burrowed in the moss. The cocoons were mostly made of silk to which were incorporated small bits of moss and other debris. Although most of the larvae dropped to the ground for pupation, a few remained on the trees. Larvae which pupated on the foliage did not spin cocoons but took shelter under the bud-caps which persist through the summer on shoots damaged by *Zeiraphera* or other defoliators.

TABLE I

Comparison of observed and calculated mean head widths (Dyar's rule) of
Griselda radicana larvae

Larval Instar	Observed mean head width	Interval	Calculated mean head width	Per cent Error
I	.20		—	—
		1.60		
II	.32		.29	9.3
		1.50		
III	.48		.43	10.4
		1.40		
IV	.67		.62	7.5
		1.30		
V	.93		.91	2.2
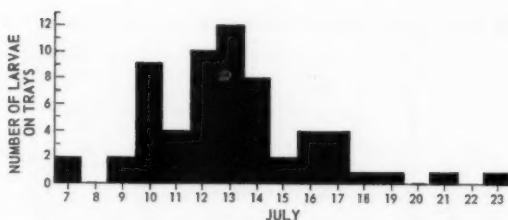
Fig. 2. Rate of drop of *G. radicana* larvae in Plot 2 as determined by the number of individuals collected from four trays measuring a total of 64 square feet.

Pupa

Pupation took place approximately two weeks after the spinning of cocoons. At first, the pupa is yellow but later turns brown. The male pupa has eight abdominal segments while the female has seven. The average length (3.65 mm.) and width (1.01 mm.) of male and female pupae did not differ significantly. The pupal stage lasted approximately three weeks.

Population Studies

Since the first- and second-instar larvae of *G. radicana* could not be differentiated from those of the two species of *Zeiraphera*, population counts could not be obtained for the earlier part of June. It is probable that populations had already been reduced through the action of natural control factors by the time a first count could be made in late June. However, at that time, *G. radicana* was the third most abundant of 14 species of defoliators encountered in the study, the two species of *Zeiraphera* being more abundant (McLeod and Blais, 1961). In spite of the position of *G. radicana* in the order of abundance, it was relatively rare and its numbers were probably at an endemic level.

Table II shows the number of larvae per 10 square feet of foliage for each of the study plots from the last week in June to the end of the third week in July. Populations of the insect varied somewhat between plots, for instance, there were approximately twice as many larvae in Plot 3 as in Plot 4. The rapid population decline in the foliage after the first week in July was a result of the larvae dropping to the ground for cocooning.

Square-foot soil samples were taken in an effort to determine cocoon populations, but insect numbers were so low that this method proved to be impracticable. An estimate of the number of larvae that dropped to the soil was gained from the number of prepupae collected on the cloth trays. These trays had been placed in Plot 2, where populations were relatively high (Table II). A total of 63 larvae dropped on a surface of 64 square feet, yielding an average of one larva per square foot. There is no doubt that in nature only a few of these larvae would survive to the adult stage.

Since *G. radicana* populations were low, and since the eggs were minute and laid singly the task of obtaining an estimate of their abundance proved impossible. The careful examination with the aid of a binocular microscope of the foliage from two full-length branches from each of the four study plots, a task that required a total of 50 man-hours, produced only five eggs.

Parasites and Predators

Notwithstanding the many difficulties experienced in rearing *G. radicana*, a total of 233 insects were reared successfully. Thirty-one per cent of these were

TABLE II

Average number of late-instar larvae of G. radicana per ten square feet of branch-surface from periodic collections made between June 19 and July 21 in four plots.

Date Locality	June							July											
	19	22	23	25	26	29	30	2	3	6	7	9	10	13	14	16	17	20	21
Plot 1 New Carlisle			16.4				15.1				13.2				5.7				2.1
Plot 2 New Richmond		20.3				15.6				9.2				9.0				0.6	
Plot 3 New Richmond				28.2				23.8				9.3				0.9			
Plot 4 Nouvelle	14.4				11.6				5.3				2.6				0.3		

parasitized.   The parasite species obtained and the host stage from which they emerged were as follows:

Parasite Species	Host-stage from which recovered
Braconidae	
Chelonus sp.	larva
Ichneumonidae	
Campoplex sp.	larva
Horogenes sp.	larva
Itoplectis quadricingulatus (Prov.)	pupa
Itoplectis vesca Tow.	pupa
Phaeogenes sp.	pupa
Triclistus pallipes Holmg.	pupa

Of the parasites recovered *Chelonus* sp. was by far the most common.

On dropping to the ground for pupation, the larvae of *G. radicana* were attacked by several species of ants.   Predation by ants undoubtedly constitutes one of the important factors of control of this insect.

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(Received February 1, 1961)

Note on the Effects of Food and Storage on the Specific Gravity, Osmotic Pressure, and Volume of Blood of Mature Larvae of *Galleria mellonella* L. (Lepidoptera: Pyralidae)

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In research on insect immunity, bacterial antigens were injected into *Galleria mellonella* L. larvae (Stephens, 1959).   It was suspected that the quality and quantity of the blood, or hemolymph, might differ if the larvae were obtained from different sources.   This note reports the effects of food and storage on the specific gravity and osmotic pressure of the blood, and of storage on the blood volume.

Larvae were reared to maturity on each of the following three diets: (a) Pablum (Mead Johnson and Co. of Canada Ltd., Belleville, Ontario), glycerine, honey and the brood comb of honey bees, *Apis mellifera* L.; (b) Pablum, glycerine and honey; and (c) diet (a) with the addition of pollen of *Pinus sylvestris* L.   The technique of Lowry and Hunter (1945) was used to determine the specific gravity of the blood, and that of Robinson (1928) to determine its osmotic pressure, and the absorption method of Richardson, Burdette and Eagle-

son (1931) was used to determine blood volume. Some larvae reared to maturity on diet (a) were stored in separate shell vials at 11.1°C. at a relative humidity of 76 per cent for 56 to 65 days. The blood volume of 12 fresh and 12 stored larvae was determined. Five larvae representing each treatment were used in the other tests. The results were analysed by the *t* test applied to the unpaired variates to determine the significance of the difference between means.

The results were as follows:

Diet	Specific gravity	Freezing point depression, °C.	Volume, ml./100g. body wt.
(a) fresh larvae	1.0545 ± .0022[1]	0.89 ± .13	42.8 ± 6.4
stored larvae	1.0625 ± .0057	1.06 ± .11	48.7 ± 11.2
(b)	1.0564 ± .0015	1.16 ± .16	
(c)	1.0458 ± .0032	0.96 ± .09	

[1]Standard deviation.

The differences between the specific gravity of the blood of fresh larvae on diets (a) and (c) and (b) and (c) are statistically significant at the .01 per cent level, but not so between (a) and (b) even at the .05 level. There are significant differences between the osmotic pressure (expressed as freezing point depression) of the blood of fresh larvae on diets (a) and (c) at the .01 per cent level, and between (a) and (b) and (b) and (c) at the .05 level. Differences in the specific gravity and osmotic pressure of the blood of fresh and stored larvae on diet (a) are significant at the .05 per cent level, but there is no significant difference between blood volumes.

Specific gravity and osmotic pressure determinations provide a rough measure of the amount of material in blood: most of the osmotic pressure is due to inorganic ions, hexose, amino and organic acids (Buck, 1953). Often when the properties of insect blood were determined no attempt was made to statistically evaluate the results, and there was little appreciation of the importance of using insects of known and controlled age, sex, developmental stage and nutritional state (loc. cit.). Our work shows that the specific gravity and osmotic pressure of the blood of mature larvae were affected by diet and increased in stored larvae though storage had no effect on blood volume. And this is evidence that the composition of the blood varied quantitatively and possibly qualitatively with the treatment of the larvae. It would therefore seem necessary in research work, where the physiology of disease and other parasitic organisms may be affected by their host's blood, to use only hosts that are very uniform, or to relate the results to the properties of the blood.

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The Cleptoparasitic Habits and the Immature Stages
of *Eurytoma pini* Bugbee (Hymenoptera: Chalcidae), a Parasite of the European Pine Shoot Moth, *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae)

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Eurytoma pini Bugbee (Bugbee, 1958), a common parasite of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.), in Ontario, was previously recorded from this host as *E. appendigaster* (Swed.) (Coppel and Arthur, 1953) and as *E. thylodermatis* Ashm. (Miller, 1953). Bugbee (1958) recorded it from various lepidopterous hosts that mine in plant tissues. These include: the Nantucket pine tip moth, *Rhyacionia frustrana* (Comst.); the bagworm, *Thyridopteryx ephemeraeformis* (Haw.); the ragweed borer, *Epiblema strenuana* (Walkr.); the lima bean borer, *Etiella* sp.; the pink bollworm, *Pectinophora gossypiella* (Saund.); *Acrobasis rubrifasciella* Packard; and *Eucosma scudderiana* (Clemens). Bugbee stated that the range of *E. pini* probably includes all of the pine growing regions of North America.

E. pini was one of seven species of indigenous parasites reared from *R. buoliana* during surveys in southern Ontario between 1950 and 1957 (Coppel and Arthur, 1954; Watson and Arthur, 1959). In addition to *E. pini*, five species, *Exeristes comstockii* (Cress.), *Hyssopus thymus* Grlt., *Scambus hispae* Harris, *Scambus tecumseh* (Vier.), and *Habrocytus* sp., were external larval parasites that paralyzed their host before depositing their eggs; the sixth was *Itoplectis conquisitor* (Say), an internal pupal parasite. During the study of the habits of *E. pini*, pine buds from which the adults of *E. pini* had emerged were dissected. Most of these buds contained the dead early immature stages of *E. comstockii* and *S. hispae*. Later studies in the laboratory showed that *E. pini* will oviposit only on inactive lepidopterous larvae. As *E. pini* emerged from infested buds previously attacked by other parasites in the field it was considered that they were depending upon these parasites to inactivate these hosts for them. For this reason *E. pini* is classified as a cleptoparasite, a term used by Evans *et al.* (1954) to describe the similar relationships of parasites of the genus *Nysson* to certain solitary wasps.

Observations on the longevity and habits of the adults were made in the laboratory at a temperature of $23 \pm 1°$ C. and 60 per cent relative humidity during the day and a temperature of $16 \pm 1°$ C. during the night and on weekends. Parasitized material was incubated at the higher temperature. The adults were fed daily with a 10 per cent aqueous solution of honey and were sprayed twice daily with water.

Development and Behaviour

Adults of *E. pini* emerged from the *R. buoliana* material between early June and late July, from one to three adults emerging from each individual host. One mating was observed, between an eight-day-old male and a three-day-old female. There was little courtship. When the male perceived the female his body swayed from side to side and he approached the female vigorously waving his antennae. The male mounted the female and the two remained *in copula* for five minutes and 40 seconds. During this time there were pronounced pulsations of the male's body accompanied by dipping of the antennae and beating of the wings.

Early attempts to rear *E. pini* in the laboratory on active hosts failed as there was no oviposition. The first clue explaining the reason for this came when four pine buds from which *E. pini* adults had emerged were examined with a microscope. Dead, immature stages of *E. comstockii* and *S. hispae* were present in three of the buds. In 1955 buds containing larvae of *R. buoliana* and larvae of the greater wax moth, *Galleria mellonella* (L.), which had been paralysed and parasitized by these ichneumon parasites were placed with females of *E. pini*. A total of 43 eggs were deposited on inactive larvae of these hosts, mostly by one female. This female also oviposited in buds that contained paralysed host larvae but not ichneumon eggs, as well as on larvae coddled for two minutes in water at 54° C. The females were not attracted to buds that contained active larvae, though such buds were offered to them several times. When searching for a host larva, the female walked over the bud very slowly with her antennae vibrating. She carefully investigated the entrance to the larval tunnel and often backed into the tunnel with her ovipositor extended. The eggs were usually deposited on the host or on the inner surface of the larval tunnel near the host. Adults of *E. pini* are relatively long-lived: ten males lived an average of 43.3 days (range 17 to 63 days); and ten females lived an average of 67.5 days (range 31 to 128 days).

Miller (1953) stated that in Ohio *E. pini* is associated with *R. buoliana* in the early part of the summer and with *Rhyacionia rigidana* (Fernald) in late summer. Some adults emerged from this latter host during the same season and he considered that the remainder would overwinter on this host. In the present study parasites reared during the late autumn entered diapause as mature larvae.

Eggs of *E. pini* hatch in approximately 40 hours at 72° ± 1° F. The first-instar larvae are very active and attack and usually kill any ichneumon eggs or larvae that are on or near the host. Sometimes older ichneumon larvae kill the *E. pini* larvae, or both larvae are killed. Laboratory observations, however, showed that larvae of *E. pini* obtained most of, if not all, their food from the primary host larva.

Subsequent dissections showed that 11 out of 14 pine buds from which adults of *E. pini* had emerged contained the dead, immature stages of other parasites. Their absence in the other three buds is not considered a negative result as ichneumon eggs or cast larval skins of the early instars are easily overlooked. Nine of these buds contained eggs or immature larvae of *Scambus* spp. and one contained a mature larva of *I. conquisitor* within a prepupa of *R. buoliana*. The fourteenth contained immature stages of *Habrocytus* sp.

Only the remains of eggs and the early larval instars of the primary larval parasites were found in the buds dissected; however, it is probable that *E. pini* also develops as a secondary parasite when it oviposits in buds containing late instar larvae of a primary parasite.

Clausen (1940) described the somewhat similar relationships of *Eurytoma monemae* Ruschka, a gregarious external parasite of the mature larva of the Oriental moth, *Monema flavescens* Wlk., within its cocoon, and *Chrysis shanghaiensis* (Smith), another parasite of the same host. In this instance *E. monemae* is unable to penetrate the thick, hard cocoon but is attracted to the ovipositing female of *C. shanghaiensis*. After this parasite has cut a hole in the cocoon, oviposited, and plugged the hole with a spongy material, the female of *E. monemae* thrusts its ovipositor through the plug and deposits its own eggs on the larva of *M. flavescens*. The relationship recorded for *E. monemae* is a further indication that other relationships similar to those of *E. pini* and its hosts may also occur within this genus.

Description of Stages

Egg

The egg (Fig. 1) is oblong in outline. It is slightly more pointed at one end than at the other. The average length of 10 eggs is 0.54 mm. (range 0.50 to 0.57 mm.), and the average width at the widest point is 0.23 mm. (range 0.21 to 0.24 mm.). The white chorion is dotted with short, black spines each approximately 0.015 mm. long. Sometimes newly-deposited eggs have white spines that change to brown and finally to black within a few hours. There is a short, fleshy pedicel approximately 0.40 mm. long on one end of the egg. This pedicel is without spines but has a sticky coating that serves to hold the egg to the substratum on which it is deposited. As this pedicel is flexible and sticky for its entire length, it is often folded upon itself or onto the adjoining portions of the egg. Only two eggs out of 43 were observed with a straight pedicel as shown in Fig. 1. There is also a flexible spine-shaped process (approximately 0.07 mm. long) on the other end of the egg.

First Instar

The first-instar larva (Fig. 2) has 13 well-defined segments, exclusive of the head. The length of one prefed larva was 0.60 mm.; the greatest width was 0.17 mm. The larva falls into Parker's (1924) group 6, and is very similar to his description of the European species *Eurytoma rosae* Nees. The head and first thoracic segment are brownish, the remainder of the larva is white. The prothoracic segment has two semi-circular processes of unknown function on the anteroventral surface. There are three pairs of spines, approximately 0.11 mm. long, on each thoracic and the first abdominal segment; and two pairs on each of the other segments except the last, which is bare.

The head (Fig. 3) is hypognathous and thimble-shaped. It is approximately 0.11 mm. wide. It bears a pair of rod-shaped antennae 0.02 mm. long and six pairs of spines that vary in length from 0.02 to 0.05 mm. The mandible (Fig. 4) has a long, curved blade without teeth and a well-developed process for articulation on each side of the base.

Second Instar

The second-instar larva differs from the first in that its segments are not so well-defined and its head is rounded like those of the succeeding instars. The length is 1.03 mm. and the widest width is 0.29 mm. There are nine pairs of spiracles, one each on the meso- and meta-thoracic and on the first seven abdominal segments. These spiracles are similar to those of the fourth instar (Fig. 8) but are smaller, with the average diameter of the atrium 0.016 mm. There are two or more pairs of spines from 0.02 to 0.03 mm. long on each body segment.

The head (Fig. 5) is 0.16 mm. wide. The average length of the fused inferior mandibular process is 0.08 mm. The antennae average 0.014 mm. in length and the spines on the head average 0.02 mm. The mandibles (Fig. 6) have shorter and straighter blades than those of the first instar.

Third Instar

The third-instar larva is similar in shape to the preceding instar, but is larger. The nine pairs of spiracles are of two size groups: those on the meta-thoracic and the fourth to seventh abdominal segments average 0.015 mm. in diameter; and those on the meso-thoracic and the first three abdominal segments average 0.023 mm. in diameter. The spines on the body also are of two sizes: the shorter ones are approximately 0.02 mm., and the longer 0.03 mm.
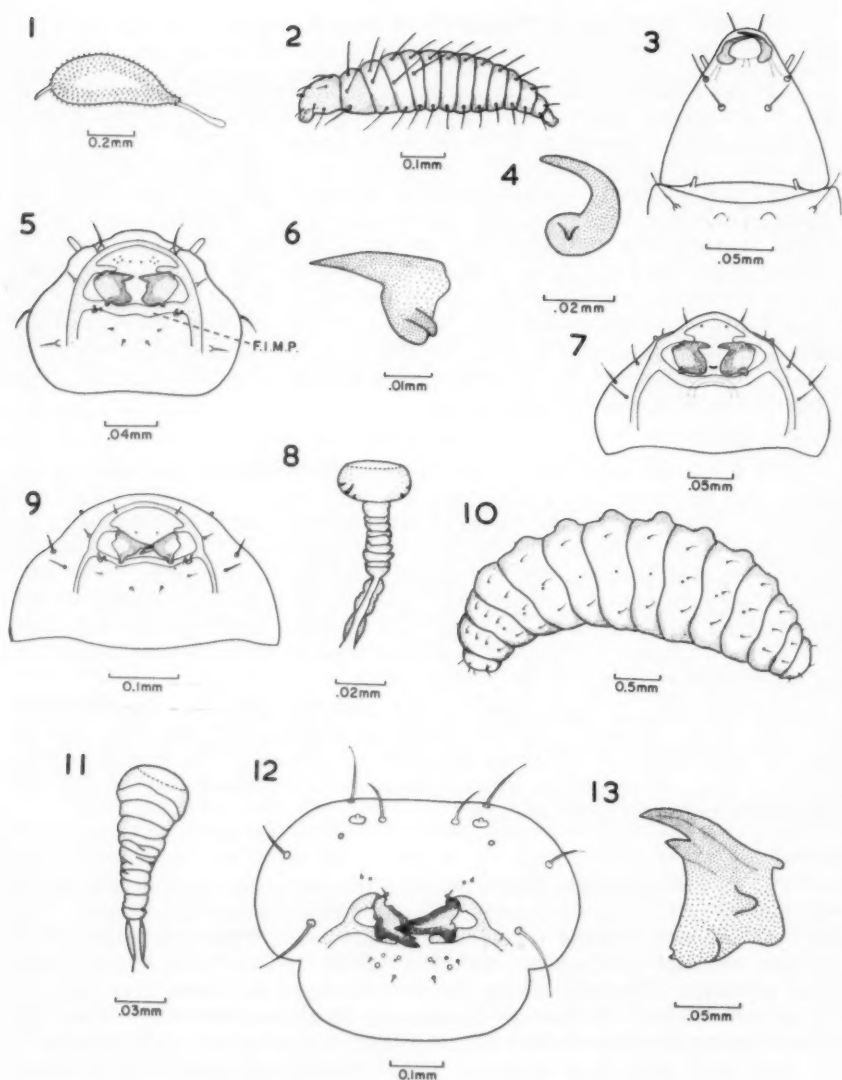
Figs. 1-13. *Eurytoma pini* Bugbee. 1, lateral view of egg; 2, lateral view of first-instar larva; 3, ventral view of head of first-instar larva; 4, mandible of first-instar larva; 5, ventral view of head of second-instar larva, F.I.M.P. = fused inferior mandibular processes; 6, mandible of second-instar larva; 7, ventral view of head of third-instar larva; 8, spiracle of fourth-instar larva; 9, ventral view of head of fourth-instar larva; 10, lateral view of fifth-instar larva; 11, spiracle of fifth-instar larva; 12, anterior view of head of fifth-instar larva; 13, mandible of fifth-instar larva.

The head (Fig. 7) is 0.25 mm. wide. The average length of the fused inferior mandibular processes is 0.11 mm. The mandibles are similar to those of the second instar except that the blades are relatively shorter.

Fourth Instar

The fourth-instar larva is approximately 1.79 mm. long and the greatest width is 0.66 mm. The size of the fourth instar varies more than that of the previous instars, probably because of the considerable difference between the sizes of the two sexes. The spiracles (Fig. 8) are of two size groups, but the difference is not as marked as in the third instar although the distribution of the large and small spiracles is the same: the larger spiracles average 0.028 mm. in diameter; and the smaller ones average 0.023 mm. The spines on the body range from 0.04 to 0.08 mm. in length. The head (Fig. 9) is approximately 0.39 mm. in width. The average length of the fused inferior mandibular processes is 0.17 mm. (range 0.16 to 0.18 mm.). The mandibles are toothless, similar to those of the previous instar. The antennae are approximately 0.015 mm. long and the spines on the head are from 0.02 to 0.05 mm. in length.

Fifth Instar

The fifth-instar larva (Fig. 10) is from 3.67 to 4.50 mm. long and the greatest width is from 1.71 to 1.76 mm. The spiracles (Fig. 11) are all approximately the same size (0.92 mm. in diameter) and have long, funnel-shaped atria. The spines on the body are from 0.11 to 0.18 mm. in length.

The head (Fig. 12) is 0.54 mm. wide. The antennae average 0.015 mm. in length and the spines on the head average 0.12 mm. long. The mandible (Fig. 13) has one large tooth which distinguishes it from the mandible of the previous instars.

Pupa

The pupa is naked, as the mature larva does not spin a cocoon. The pupa is whitish when first formed but darkens to black before emergence. Bugbee (1958) stated that the length of the adult male averages 3.0 mm. (range 2.6 to 3.1 mm.) and that of the female is 4.5 mm (range 3.9 to 5.2 mm.). The length of the pupa is similar to that of the adult. The height of the abdomen (distance from sternum to tergum of same segment) is greater than its width.

Separation from Other R. buoliana Parasites

The immature stages of the parasites attacking the larvae and pupae of *R. buoliana* can all be found within the host larval tunnel. The following characters will serve to distinguish the immature stages of *E. pini* from those of all other recorded parasites of *R. buoliana* in Canada: only the egg of *E. pini* has a chorion dotted with brownish or black spines and a fleshy pedicel; only the larvae of *E. pini* has long spines on the head and body; only *E. pini* has one distinct tooth on the mandible of the mature larva; and the pupa of *E. pini* is naked, like other chalcid parasites of *R. buoliana*, but differs from them in that the height of the abdomen from sternum to tergum is greater than the width.

Summary

Eurytoma pini Bugbee is a parasite of *Rhyacionia buoliana* and of several other stem-boring Lepidoptera. Dissection of pine buds from which adult *E. pini* had emerged revealed the presence of the early instars of various primary parasites that paralysed the host before oviposition. In the laboratory females of *E. pini* would not oviposit on active host larvae but would do so after those

larvae had been paralysed by another parasite or by coddling in hot water. These observations lead to the conclusion that in the field *E. pini* oviposits on larvae that had previously been inactivated by other species of parasites. For these reasons *E. pini* is classified as a cleptoparasite.

Descriptions of the immature stages of *E. pini* with a list of the characters which distinguish it from other parasites attacking *R. buoliana* in Canada are given.

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(Received March 6, 1961)

Notes on *Anthocoris melanocerus* Reuter (Hemiptera: Anthocoridae) as a Predator of the Pear Psylla in British Columbia[1]

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The role of natural enemies in the control of the pear psylla, *Psylla pyricola* Foerst., has been of minor importance in the published history of this pest in North America. Jensen (1957) listed six species of parasites that attack the pear psylla nymph, but only one, *Psylledontus insidiosus* Cwfd. (Hymenoptera: Encyrtidae), is recorded from North America. Slingerland (1896) stated that the predators *Chrysopa oculata* Say (Neuroptera: Chrysopidae) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) were observed in the field feeding on psyllid eggs, nymphs and adults. Georgalla (1957) reported that *Anthocoris nemorum* L. (Hemiptera: Anthocoridae) fed upon pear psylla eggs and nymphs, but made no reference to effect upon psyllid populations.

The observations recorded in this paper were obtained during the course of an investigation on the control of pear psylla by means of dormant sprays. The orchard under study was located near Summerland, British Columbia, and the number of overwintered adult psyllids was extremely high. The orchard was divided into plots and treated with oils of varying viscocity, oil-dinitro, oil-lime sulfur and polybutene at the dormant period in late March. Twig and leaf samples were taken at intervals throughout the season to ascertain the effects of

the sprays upon pear psylla, and while sampling and making counts, anthocorids were noted feeding upon psyllid eggs and nymphs. The species involved was determined as *Anthocoris melanocerus* Reuter with the aid of a key developed by Anderson (1958). His study recorded two species, *Anthocoris antevolens* White, and *A. melanocerus*, as occurring in British Columbia, with the latter species being most commonly encountered from Summerland north. They were both listed as predators of aphids in fruit orchards, but the pear psylla was not mentioned as a host of either species.

The first anthocorids seen on April 7 were overwintered adults, and they were fairly abundant in the orchard. They were observed feeding upon psyllid eggs, which at that time were numerous on the fruit spurs and opening buds. The anthocorids were distributed over the several dormant spray plots, and there was no indication that any one treatment was exerting an adverse effect on the bugs. On April 13, when the pear leaves had opened, anthocorid eggs were evident on the leaf samples collected for pear psylla counts. No further anthocorid activity was noted on subsequent leaf samples until June 6, when a few anthocorid nymphs were seen. No significance was attached to their presence because the pear psylla population was rapidly increasing.

On July 5 a leaf sample showed numerous anthocorid nymphs. In addition, the pear psylla population, which had been steadily rising, showed no increase over the previous count made a week previously. Many of the drops of honeydew that were present had no psylla nymphs in association, and others had only the dried exoskeleton. It was suspected that anthocorids may have been responsible for this phenomenon. An attempt was made to estimate the anthocorid population by a beating method. An umbrella was used as a beating tray. It was held under a pear limb, and the limb struck with a rubber mallet. At that time one section of the test orchard had not been treated since the dormant period, and another section had received a summer spray of Dimethoate (0, 0-dimethyl S(N-methyl carbamoylmethyl) phosphorodithioate on June 2. Samples were taken in the dormant sprayed and summer sprayed sections. One limb on each of 10 trees was sampled in each section. In the area that had received only a dormant spray, the average number of anthocorid nymphs per sample was 20.7. In the Dimethoate-sprayed area there were 2.0 anthocorids per sample.

Leaf samples were taken from fruit spurs to determine the number of anthocorid eggs, most of which had hatched. The numbers of eggs on July 5 were as follows: dormant sprayed trees, 28 eggs per 100 leaves; summer sprayed trees, 6 eggs per 100 leaves.

There was then in this orchard a moderately high population of anthocorids, and a considerable difference in numbers between trees sprayed during the dormant season and those treated with a summer spray.

In the laboratory, anthocorids were observed while they were feeding upon psylla eggs and nymphs. The insects seemed to search at random, often walking over the eggs before selecting one on which to feed. They inserted their stylets into an egg and remained motionless until they had extracted the contents. In the single case in which an anthocorid was observed feeding on a pear psylla nymph, it probed with its beak in several drops of honeydew until it located a psyllid nymph. It then pierced the body of the nymph with its mouthparts and lifted its prey out of the honeydew. Then, prey on its mouthparts, the anthocorid wandered about the leaf until it had removed the body contents, whereupon the dry exoskeleton was discarded. From the time the prey was first located until feeding was complete, the performance required two minutes.

Counts of pear psylla during the next three weeks showed a decrease in the number of nymphs even though adult psyllids were present and eggs were being laid. In the dormant sprayed section the average number of pear psylla nymphs per leaf was 3.5 on July 5; the number declined to 0.5 on July 18, and increased slightly to 0.8 an July 26. During this period extremely hot weather also served to hold the pear psylla in check. Maximum temperatures during mid July were 90°F. for 16 days, with only four days below 84°F., and many drops of honey-dew became solidified as described by Marshall (1959). As both the hot weather and predation were occuring at the same time, it was not possible to determine the actual biological control affected by anthocorids. Observations in other orchards showed that anthocorids were present in varying numbers.

Adult anthocorids were again evident on and after July 18, and eggs of a new generation were laid in the leaves. According to the life history studies of *A. melanocerus* by Anderson (1958), the nymphs observed in June represented the first summer generation, and the nymphs recorded in July were the second generation. A third, and overwintering generation would develop from the eggs laid in late July.

A codling moth cover spray was applied to the entire orchard in early August, and the observations on anthocorids were therefore discontinued.

These observations, although preliminary, indicate that anthocorids may play a role in the natural control of the pear psylla. Dormant treatments apparently are less harmful to anthocorids than summer sprays with contact and residual insecticides. In areas where it may not be necessary to apply chemicals early in the season for insect control, this practice may permit the increase of natural enemies such as *A. melanocerus*. In any case, with an insect as potentially destructive as the pear psylla, and as capable of developing resistance to insecticides, it would be desirable to have increased knowledge of the ecological factors that may serve to hold this pest in check.

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A New Species of *Gerris* F. from Yukon and Alaska
(Hemiptera: Gerridae)

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Two species that formerly were confused in the literature with *Gerris rufoscutellatus* Latreille are *G. notabilis* Drake and Hottes (1925) from western North America, and *G. dissortis* Drake and Harris (1930) from eastern North America. Drake and Harris (1934) concluded that Palaearctic *rufoscutellatus* did not occur in America.

The species described herewith as *Gerris nearcticus* n. sp. is similar to *notabilis, dissortis* and *rufoscutellatus* in general appearance and coloration. However, the males are readily separated from *notabilis* and *dissortis* by the prominent median keel on the first genital segment (Figs. 1, 2). Another Nearctic species with a similar median keel is *G. conformis* (Uhl.), but it has a very long first antennal segment, which is longer than segments two and three together. The first antennal segment of *nearcticus* is much shorter than segments two and three together.

The new species is separated from *rufoscutellatus* by the relative lengths of the tibiae: in the former the second tibia is shorter than the third, whereas in the latter the second tibia is longer than the third. It is also distinguished from *rufoscutellatus* by the smaller size, more convex median keel in the male, shorter rostrum and conexival spines in both sexes, and differences in the genitalia. The species belongs to the subgenus *Limnoporus* Stål.

Gerris nearcticus, new species
(Figs. 1-5, 11, 13)

Male:—Elongate, reddish brown. Pronotum with a large black spot each side of median line in front; sides with a broad yellowish brown line; median ridge distinct, paler in colour. Nervures of hemelytra brownish black with short, golden pubescence. Antenna: I, 2.38-2.52 mm., brown; II, 1.82-1.96 mm., brown; III, 1.4-1.47 mm., brown; IV, 1.75-1.89 mm., dark brown, apex lighter. Body beneath with silvery hairs. Segments 3 and 4 of rostrum 2.24-2.38 mm. long. Length, 12.67-14.0 mm.; width of pronotum, 1.96-2.24 mm.

Female:—Very similar to the male in coloration, but slightly larger in size. Antenna: I, 1.96-2.17 mm.; II, 1.33-1.68 mm.; III, 1.02-1.4 mm.; IV, 1.75-1.82 mm. Segments 3 and 4 of rostrum 2.24-2.52 mm. long. Length, 13.58-16.31 mm.; width of pronotum, 2.24-2.38 mm.

Holotype:—Male, Rampart House, Yukon Territory; 6.VI.1951; C. C. Loan. No. 7414 in the Canadian National Collection of Insects, Ottawa.

Allotype:—Female, same data as for holotype.

Paratypes:—4 ♂ ♂, 6 ♀ ♀, same data; 1 ♂, 4 ♀ ♀, Snag, Yukon Territory, 22.VII.1948, Mason and Hughes; 1 ♂, 3 ♀ ♀, Skilak Lake, Kenai Peninsula, Alaska, 26.V.1951, W. J. Brown; 2 ♀ ♀, Lake Beaulieu, 11 mi. S. Big Delta Jct., Alaska, 19.V.1951, W. J. Brown.

Summary

Gerris nearcticus n. sp. is described from Yukon Territory and Alaska. It is most closely related to *G. rufoscutellatus* Latr. of Europe. Distinguishing external and genitalic characters for the two species are given.
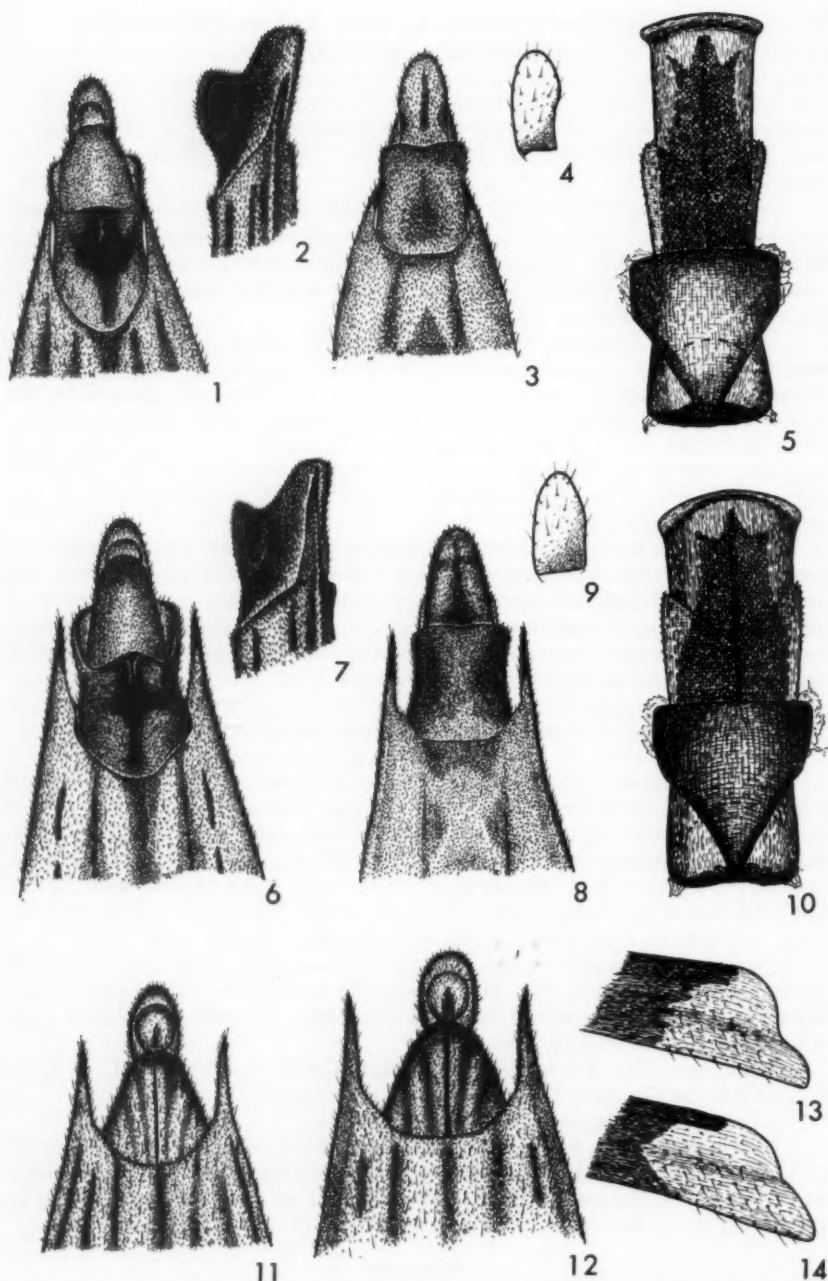
Figs. 1-14. Male and female genitalia of *Gerris spp.* 1-5, 11, 13, *Gerris nearcticus* n. sp.; 6-10, 12, 14, *Gerris rufoscutellatus* Latr.; 1-3, 6-8, male genital segments, ventral, lateral, and dorsal view; 4, 9, left claspers, lateral view; 5, 10, vesicae, dorsal view; 11, 12, female genital segments, ventral view; 13, 14, left anterior valvulae.

Acknowledgments

I wish to express my sincere thanks to Dr. Carl J. Drake, United States National Museum, for drawing my attention to the species complex, and for specimens of *rufoscutellatus;* and to Dr. G. G. E. Scudder, University of British Columbia, for European specimens.

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(Received December 9, 1960)

Developmental Patterns of the Clear-Winged Grasshopper at Different Altitudes and in Different Years on a Sheep Range in British Columbia, Canada[1]

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It has long been known that life events occur earlier at lower than at higher altitudes (Hopkins, 1918; Chapman, 1931; Uvarov, 1931). Treherne and Buckell (1924) refer specifically to the earlier appearance of the clear-winged grasshopper, *Cammula pellucida* (Scudder), near Nicola Lake, B.C., (2020 ft.), as compared with its appearance at nearby but higher places such as Douglas Lake (2600 ft.) and in the areas between Minnie Lake and Aspen Grove "where the elevation at many points exceeds 3500 feet." These references, and the possibility of using the knowledge to help determine dates when control operations may be necessary on various ranges in any one season, suggested the need for more precise measurements of the development of this major rangeland pest at different altitudes in different years.

Site of Observations

Sampling and observations were made on open range from four to twelve miles northwest of Kamloops at elevations of 2100, 2300, 2600, and 3000 feet. More uniform vertical spacing would have been advantageous but sites capable of supporting adequate numbers of *C. pellucida* in non-outbreak years were relatively few; an observation point at 1200 ft. was dropped at the end of three years because of low numbers, nor could any other suitable site be found between 1200 and 2100 ft., a zone in which sagebrush is abundant.

Methods

During the spring and early summer of the years 1953 to 1958, inclusive, a sample of specimens was collected from each site at approximately weekly intervals. Since sunny, calm weather was required in the interests of uniformity, some flexibility was necessary in the chronological spacing. Thus some of the mean instars used to calculate the general mean instar of a given date may have been based on collections made one to three days before or after that date.

All the specimens taken in 100 strokes of a 15-inch net constituted a sample; all sampling was done by the author following the same course over the observation sites each time. During periods of low populations, especially during the earlier part of the season in some years, net strokes were increased to 200. Collections were stored in 70 per cent alcohol in pint fruit jars until the stage of development was determined.

Mean stage of development was calculated by multiplying the number of specimens in each instar by the instar number plus one-half, adding the products thus obtained, and dividing by the total number of specimens. This varies only slightly from the method used and reported by Moore (1945).

Example:

$$3 \text{ second instar} \times 2.5 = 7.5$$
$$8 \text{ third instar} \times 3.5 = 28.0$$
$$18 \text{ fourth instar} \times 4.5 = 81.0$$
$$7 \text{ fifth instar} \times 5.5 = 38.5$$

Totals   36   155.0

Average stage of development $= 155 \div 36 = 4.3$

There is a minor lag in apparent development during the early part of the season due to the fact that newly hatched specimens are occasionally added and consequently "dilute" the sample. However, C. pellucida tends to hatch during a shorter period than do the other pest species; this occurs largely as a result of the earlier deposition of eggs in the autumn and the consequent chance that all will reach diapause which, in turn, also occurs at an earlier stage of embryogenesis (Moore, 1948). Another factor that may reduce to a small extent the calculated mean instar, especially in earlier, warmer years, is any tendency the older nymphs may have, as compared with younger ones, to wander from the sampling area.

All temperature data used for comparative purposes in this paper were obtained from the records of the official station at Fulton Field Airport at 1100 ft., just below the sampling area. Data are available for short periods for other altitudes on the Lac du Bois range, but only enough to give a rough approximation of the differences that may be expected. During the period under study, April 1 to June 15, temperatures at 3000 ft. apparently were about 10 degrees lower than those at 1100 ft. For this reason, and because base temperatures for plant growth (and the calculation of degree-days) range from 36°F. for spinach to 59°F. for tomatoes (Holmes and Robertson, 1959), 60°F. at 1100 ft. was taken arbitrarily as the base temperature for calculating degree-days; the true base temperature for the development of C. pellucida is unknown.

Results

Fig. 1 shows that development was earliest in 1958 and latest in 1955, development during the other four years ranging between. There were also indications of some form of periodicity, the trend being later each succeeding year from 1953 to 1955 and earlier each succeeding year thereafter. Thus by mid-June the mean nymphal stage during each of the years 1953 to 1958 was 3.72, 2.76, 2.69, 3.81, 4.58 and 5.57, respectively. Interpolating on the basis of the graph in Fig. 1, a mean instar of 1.65 was reached by May 31 in 1955. This was five days later than the same stage was reached in 1953, six days later than it was reached in 1954, 9.5 days later than in 1956, 11 days later than in 1957, and 18.5 days later than in 1958. The mean instar of 2.69, reached by June 15 in 1955, was one day later than that stage
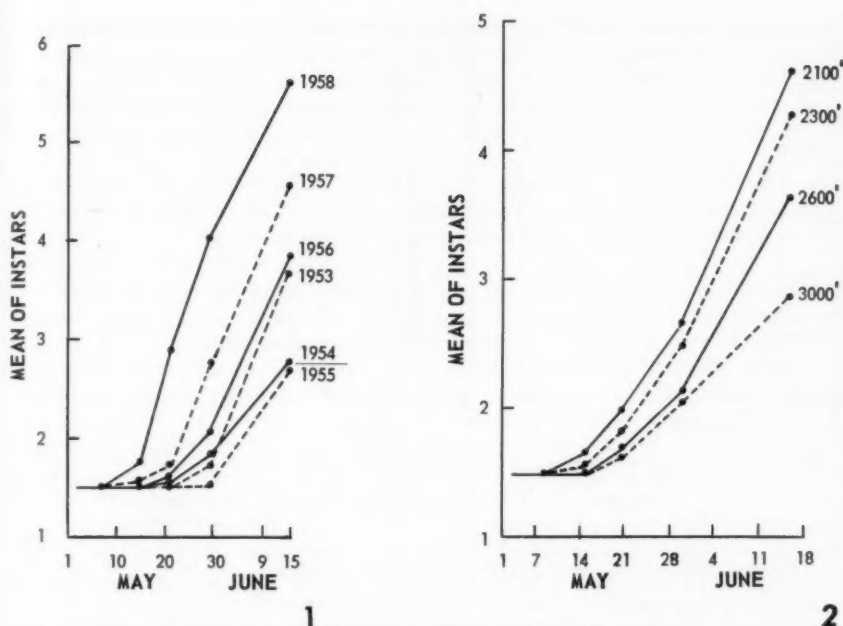
Figs. 1-2. 1. (left)   Mean nymphal development of the clear-winged grasshopper from May 1 to June 15, for each of six years, on a British Columbia sheep range; mean of collections at four altitudes.   2. (right)   Mean nymphal development of the clear-winged grasshopper from May 1 to June 15, at four altitudes, on a British Columbia sheep range; mean of collections during six years.

was reached in 1954, 8.5 days later than in 1953, 10.5 days later than in 1956, 16.5 days later than in 1957, and 24.5 days later than in 1958.

Fig. 2 shows the mean differences in stage of development of C. *pellucida* to mid-June at four altitudes for the years 1953 to 1958, inclusive.   Thus by mid-June the mean nymphal stage of the six years was 4.62 at 2100 ft., 4.28 at 2300 ft., 3.65 at 2600 ft., and 2.86 at 3000 ft.   Again interpolating from the graph in Fig. 2, it is apparent that nymphs at 3000 ft., reached mean instar 2.08 on May 21, 2.5 days later than those at 2600 ft., 6.5 days later than those at 2300 ft., and 8.5 days later than those at 2100 ft.   By June 15, nymphs at 3000 ft. had reached mean instar 2.86, 8.5 days later than those at 2600 ft., 12.5 days later than those at 2300 ft., and nearly 15 days later than those at 2100 ft.

The close relationship between total degree-days above 60° F., during the period April 1 to June 15 of a given year, and mean nymphal development on June 15 of that year, is apparent from Fig. 3, A.   This relationship is the more striking when one considers that the temperature data were obtained at 1100 ft. and the records of development from 2100 ft. to 3000 ft.   However, the relationship was almost as close when development was compared with either the degree-days above 50° F. or the mean temperature for the developmental period.

Discussion

The data presented in this paper clearly indicate the wide differences that may be expected from year to year in the development of C. *pellucida* on British Columbia rangelands, and the close relationship of these differences to differences

3 A   **3 B**
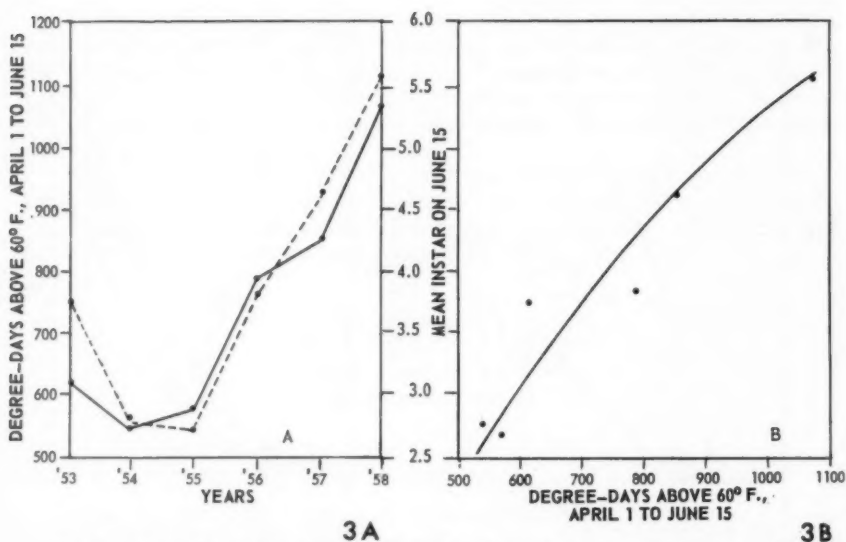
Fig. 3. (right) Mean instar of the clear-winged grasshopper on June 15 as related to total degree-days above 60°F. from April 1 to June 15 over a period of six years; mean of collections at four altitudes.

In Fig. 3 A, (left), broken line connects mean instars and solid line connects total degree-days.

in temperature. This relationship is so close, in fact, that one might be tempted to suggest that curve B of Fig. 3, where mean instar for each year is plotted against total degree-days above 60° F. for the corresponding year, supports the mathematical formula presented by Pradhan (1946). The temperature data were, however, inadequate for the calculations required.

Concerning the effects of altitude, Kennington (1957) found that populations of the carpenter ant, *Camponotus pennsylvanicus modoc* Wheeler, native to 10,600 ft., consumed oxygen at significantly greater rates when the temperature was raised from 10° C. to 25° C. than did those native to 6750 ft. This occurred regardless of whether the experiment was conducted at 10,600 ft. or 6,750 ft., but the change in consumption with higher temperature was greater at the higher altitude in both strains of the species. Shapley (1920), working with *Liometopum apiculatum* Mayr at 5700 ft. on Mount Wilson, California, found that the speed of travel of the ant could be predicted within an average probable error of five per cent for temperatures from 8° C. to 38° C. He concluded that the effects of light, time of day, wind, relative humidity, and atmospheric pressure were extremely small by comparison. The data on *C. pellucida* were not collected to show differences due primarily to altitude as distinct from temperature, but considering the short vertical distance involved (only 900 ft.), and considering the results obtained by Kennington and by Shapley, it seems likely that the effect of altitude alone would have been very small, nor is there any indication that biotypes adapted to different altitudes were involved. Although meteorological data for the higher altitudes were insufficient to permit definite conclusions as to the precise role played by temperature in the rates of development of *C. pellucida* at the different altitudes, the few readings available indicated a difference of about 10° F. between 1100 ft. and 3000 ft. during spring and early summer. For this

reason, and again considering the results obtained by Shapley and by Kennington, it would appear reasonable to assume that differences in degree-days had a major effect.   Be that as it may, the differences in time (and apparently rate) of development at different altitudes were quite marked and apparently consistent; the mean difference between 2100 ft. and 3000 ft. by June 15 was approximately 15 days, or 1.67 days for each 100 ft. of altitude.   This is nearly twice the difference indicated by Hopkins (1918) for periodical life events generally.   The discrepancy may be due in whole or in part to (1) the relatively dry conditions, (2) the very light shadow cast by the sparse vegetation, or, especially, (3) the general southerly slope of the area under study.

Regardless of the inadequacies of supporting data for the definite demonstration of causal effects, the data on development are complete and have the practical advantage of indicating the over-all differences that can occur in both embryological and nymphal development.   It is believed, therefore, that they will prove useful in planning campaigns for controlling *C. pellucida* on B.C. ranges.   It has been found[2] that *C. pellucida*, up to and including the third instar, consumes so little range fodder that it is worth while delaying control operations until the main hatch reaches that stage.   By that time most of the eggs will have hatched and a better chance is provided that control measures will not have to be repeated during any one season.   If a control zone operator knows of a conveniently located egg bed of *C. pellucida*, and observes the hatch and development thereon, he can probably predict the date on which the third instar will be reached on other egg beds at the same or different altitudes; this presupposes, of course, a fairly accurate knowledge of the zone's topography on the part of the control zone operator, and also the probability that egg beds, and hence the concentration of early-instar nymphs, are not too widespread.

Summary

Marked differences were observed in the development of the clear-winged grasshopper, *Camnula pellucida* (Scudder), in different years and at different altitudes on a sheep range in British Columbia.   The difference in development from year to year was closely related to heat units; for example, a mean instar of 2.69, reached by June 15 in 1955, when the degree-days above 60° F. to June 15 totalled 572, was about 24.5 days later than the date on which that instar was reached in 1958 when the degree-days to June 15 totalled 1075.   At an altitude of 3000 ft. development by June 15 averaged about 15 days later than it did at 2100 ft.   This difference is nearly double that indicated for periodical life events by Hopkins' Bioclimatic Law.   It is believed that the results obtained in this study may be useful in planning the control of *C. pellucida* on B.C. range lands.

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(Received December 28, 1960)

Mosquitoes Feeding on a Frog[1]
By L. BURGESS[2] AND G. H. HAMMOND[3]

In the spring of 1957, Mr. K. J. Crawford, Gananoque, Ontario, took some interesting photographs of some mosquitoes that were feeding on a frog. With Mr. Crawford's kind permission, we reproduce one of these photographs (Fig. 1). This photograph was taken among the reeds of a swampy depression a few miles north of Marmora, Ontario. As it was taken early in the season, April 26 to be
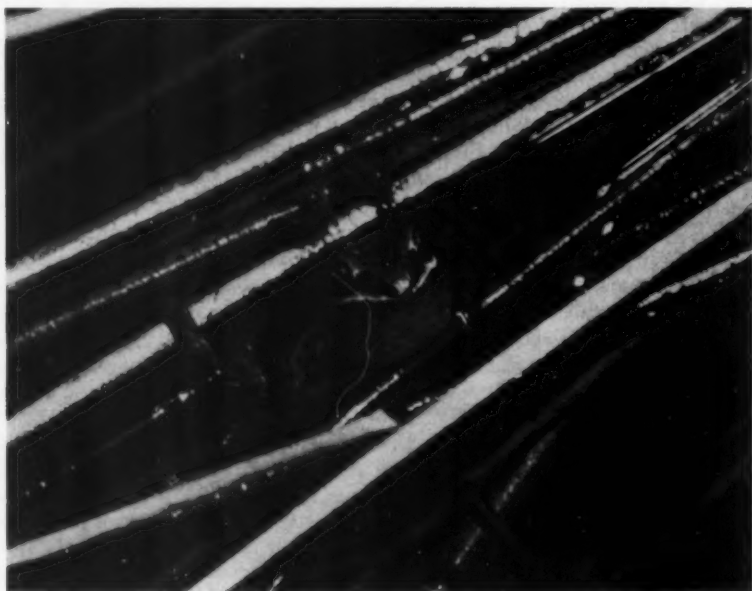
Fig. 1. Mosquitoes feeding on a frog in a natural habitat.

exact, the mosquitoes had probably overwintered as adults. They attacked the frog fiercely, but did not bother the photographer. The mosquitoes can not be identified with certainty from the photograph, but they probably belong either to the genus *Culex* or the genus *Culiseta*. The evidence suggests that they are *Culex territans* Walker. This species probably overwinters in the adult stage in Ontario, is a known amphibian feeder, and is not believed to attack man (Carpenter and LaCasse, 1955).

It is interesting to note that the mosquitoes are resting mainly on the reeds rather than on the frog's body as they attempt to bite. The frog has been identified as the western chorus frog, *Pseudacris negrita triseriata*.

Acknowledgments

The authors extend their thanks to Reverend K. J. Crawford, Gananoque, Ontario, who took the photographs, and to Dr. E. B. S. Logier, Curator of Reptiles and Amphibians, The Royal Ontario Museum, Toronto, Ontario, who confirmed the identification of the frog.

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(Received July 9, 1960)

The Influence of Spray Programs on the Fauna of Apple Orchards in Nova Scotia. XII. Second Supplement to VII. Effects on Beneficial Arthropods[1]

By A. W. MacPhee and K. H. Sanford

The design of orchard pest control programs that favor natural enemies is based partly on a knowledge of the toxicity of spray chemicals to beneficial arthropods. This paper summarizes the results of tests conducted during the past five years to determine toxicities, and it includes some previously published data (MacPhee and Sanford 1954 and 1956). Tests were discontinued after 1955 on the species *Stethorus punctum* (Lec.), *Euderus* spp., *Scambus* spp., and *Trichogramma minutum* Riley and on the chemical formulations Aramite, Chlorocide, Erad, fixed nicotine, lime sulphur, Puratized Agricultural Spray, summer oil, and synthetic cryolite. Tests were initiated on the phytoseiids *Typhlodromus finlandicus* (Oudms.) and *T. rhenanus* (Oudms.), and the mirid *Psallus* sp., and also on the pesticides *Bacillus thuringiensis* Berliner preparation, demeton, Diazinon, dodine, Kelthane, Kepone, Rhothane, Sevin, Tedion, Trithion and zineb. *Typhlodromus pyri* Scheuten was previously reported as *T. tiliae* (Oudms.), a synonym, and *Atractotomus mali* (Meyer) is an authoritative identification of the species previously listed as *Criocoris saliens* (Reuter).

Procedure and Results

Small plots of two to four trees in commercial orchards were used for the tests. The tests were replicated in several orchards and treatments applied at the concentrations shown in Table I. The lower dosages of some insecticides were tested to determine their selective effect on predators since reduced rates have value in controlling certain pests.

TABLE I

Effects of spray chemicals on predator and parasite populations in Nova Scotia orchards

Predator(s) and Parasite(s)	Spray chemical — amount per 100 gallons water	*Bacillus thuringiensis* preparation[1] 4 lb.	*Bacillus thuringiensis* preparation 1 lb.	Bordeaux (3 lb. copper sulphate + 10 lb. lime)	Calcium arsenate 3 lb.	Captan 2 lb.	Demeton (26.2% emul. conc.) 1 pt.	DDT (50% w.p.) 2 lb.	DDT 0.5 lb.	DDT 0.25 lb.	DDT 0.125 lb.	Diazinon (25% w.p.)[2] 2 lb.	Diazinon 0.5 lb.	Diazinon 0.25 lb.	Diazinon 0.125 lb.	Diazinon 0.062 lb.	Dichlone 0.5 lb.	Genite (50% Emul.)[3] 1.5 pt.	Glyodin 1.5 qt.
Acarina																			
Anystis agilis Banks		-*	-	o	+	o	-	++	++	++	o	+	o	-	o	o	o	-	+
Mediolata novaescotiae Nes.		-	-	o	-	o	-	o	o	o	-	-	o	-	-	o	o	++	+
Phytoseius macropilis Banks		-	-	-	-	o	-	-	++	++	-	-	-	-	-	-	o	+o	+
Typhlodromus finlandicus (Oudms.)		-	-	-	-	-	-	-	+	+	-	-	++	++	-	-	-	+	
Typhlodromus rhenanus (Oudms.)		-	-	-	-	-	-	++	+	+	o	-	+	++	-	-	+	+	+
Typhlodromus pyri Scheuten		-	-	+o	+o	o	-	+	+	+	o	-	+	+	-	-	+	+	o
Miridae																			
Atractotomus mali (Meyer)		-	-	-	-	o	-	++	++	++	+	+	-	-	-	+	+	+o	o
Campylomma verbasci (Meyer)		o	-	-	-	-	-	+o	+o	-	-	-	++	++	-	-	o	o	o
Deraeocoris fasciolus Knight		-	-	o	o	-	-	++	o	o	o	++	+o	+o	+o	+o	o	o	o
Deraeocoris nebulosus (Uhl.)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphnidia spo.		-	-	o	-	-	-	++	-	-	-	-	-	-	-	-	-	+o	o
Hyaliodes harti Knight		o	o	o	o	o	+	+	+	+	o	-	++	+	+	+	o	o	o
Phytocoris spp.		-	o	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
Pilophorus perplexus D. & S.		-	-	-	-	o	-	++	+	-	-	-	-	-	+	+	o	+o	o
Plagiognathus obscurus Uhl.		-	-	o	-	-	-	++	o	o	+	++	++	++	-	-	o	+o	o
Psallus sp.		-	o	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Anthocoridae																			
Anthocoris musculus (Say)		o	o	-	o	o	+	+	o	o	o	++	++	+	+	+o	o	+	o
Thysanoptera																			
Haplothrips faurei Hood		o	-	o	o	o	-	++	++	+	+	++	++	-	+	-	o	+	o
Leptothrips mali (Fitch)		-	-	-	-	o	-	++	++	+	-	-	-	-	+	-	o	o	o
Parasitic hymenoptera																			
Aphytis mytilaspidis (LeB.)		-	-	o	-	o	-	++	-	o	-	+	-	-	-	-	o	-	o

*No information, -; no effect, o; reduction of numbers, +; practical elimination, ++; possible reduction, evidence inconclusive, +…

[1]Wettable powder preparation of *B. thuringiensis* Berliner spores (Rohm and Haas Co.) (75 x 10⁶ spores per gram).
[2]*O, O*-Diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidyl) phosphorothiate (J. R. Geigy A.G.).
[3]2,4-Dichlorophenyl benzene sulfonate (Allied Chem. Corp.).
[4]*O,O*-Dimethyl *S*-(4-oxo-benzotriazine-3-methyl) phosphorodithioate (Chemagro Corp.).
[5]4,4'-Dichloro-α-trichloromethylbenzhydrol (Rohm and Haas Co.).

The susceptibility of each species to pesticides varies, and some materials have wider spectra of toxicity than others. Demeton, DDT, Diazinon, malathion, parathion and Sevin at recommended dosages were harmful to all species tested. Guthion, Perthane, Rhothane and Trithion were harmful to most species. Genite, lead arsenate, nicotine sulphate, Tedion and wettable sulphur were harmful to some but relatively innocuous to others. Treatments with *B. thuringiensis* preparation, Bordeaux, calcium arsenate, captan, dichlone, dodine, ferbam, glyodin, Kelthane, Kepone, ovex, ryania, and zineb caused little or no reduction of most species. The low dosages of DDT, Diazinon, Guthion, malathion, parathion, and Trithion were relatively harmless to some beneficial species.

The results reported here have been used in selecting pesticides least harmful to beneficial species and in selecting materials effective in the removal of unwanted biotic control agents in the study of particular predator-prey interrelationships. The choice of the most suitable materials is based on a knowledge of the complex of active control agents present in the area. Some of the pests with control chemicals used in an integrated spray program in Nova Scotia, are: Apple scab — captan, dodine, glyodin or dichlone; European red mite — ovex or kelthane; codling moth — ryania; apple maggot — lead arsenate; apple sucker —

TABLE I—CONTINUED

		Dichlone		Gentle (50% Emul.)[3]	Glyodin	Guthion (65% w.p.)[4]	Guthion	Kelthane (25% w.p.)[5]	Kelthane	Kepone (50% w.p.)[6]	Lead arsenate	Malathion (25% w.p.)	Malathion	Malathion	Malathion	Malathion	Nicotine sulphate	Ovex (50% w.p.)	Parathion (15% w.p.)	Parathion	Perthane (25% w.p.)[7]	Rhothane (50% w.p.)[8]	Ryania (50%–6 lb.) or (100%–5 lb.)	Sevin (50% w.p.)[9]	Sevin	Tedion (50% w.p.)[10]	Trithion (25% w.p.)[11]	Thrithion	Wettable sulphur	Zineb (50% w.p.)
0.5 lb.				1.5 pt.	1.5 qt.	1 lb.	0.125 l.b.	2 lb.	1 lb.	2 lb.	4 lb.	2 lb.	1 lb.	0.25 lb.	0.125 lb.	0.062 lb.	1 pt.	0.5 lb.	0.75 lb.	0.19 lb.	3 lb.	2 lb.		2 lb.	1 lb.	0.5 lb.	1 lb.	0.25 lb.	8 lb.	2 lb.

Decachloro-tetrahydro-4,7-methanoindenone (Allied Chem. Corp.).
1,1-bis (p-ethylphenyl)-2,2-dichloroethane (Rohm and Haas Co.).
2,2-bis (p-chlorophenyl)-1,1-dichloroethane (Rohm and Haas Co.).
N-Methyl-1-naphthyl carbamate (Union Carbide Chemicals Co.).
2,4,5-4'-Tetrachlorodiphenyl sulphone (Niagara Chemical Co.).
0,0-Diethyl S-p-chlorophenylthiomethyl phosphorodithioate (Stauffer Chem. Co.).

nicotine sulphate or guthion (0.125 lb.); cankerworm – lead arsenate or DDT (0.125 lb.).

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Lectotype Designations in the New World Myrmeleontidae

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During the month of August, 1960, I had the opportunity of studying the extensive collection of ant-lions at the Museum of Comparative Zoology, Harvard University. This collection contains most of the type material of Nathan Banks and Hermann Hagen. In many cases only syntypes were present which necessitated the designation of lectotypes. Whenever possible I have selected and designated a male specimen as the lectotype since many of the specific characters are restricted to the males. Others of the syntypical series were labeled lectoparatypes. In many instances one specimen had a "type" label and the rest of the series "paratype" labels or no labels at all. However, these labels were not considered to be type designations as they were not indicated as such in the original descriptions. The specimens were therefore considered to be syntypes. Also, in checking the specimens listed in the original descriptions with the available material, it was sometimes found that other specimens belonged to the type series, even though they were not so labeled. I have included such specimens in my decisions on lectotypes.

Banks, in his 1927 revision, indicated the type localities for many species described by Hagen and himself by putting the word "type" in parenthesis following the locality. For three species, *Brachynemurus nigrilabris* Hagen, *B. peregrinus* Hagen, and *Maracanda signata* Hagen, this constituted lectotype designation as there is only one specimen for each of the type localities. To make clear the type situation, I therefore placed a lectotype label on each of these three specimens. The reader is referred to the discussion under each species for more information.

A red M. C. Z. label with the prefix L- written before the word "type" was placed on all of the lectotypes. The rest of the syntypes were similarly labeled with the prefix L- written before the word "paratype". Also, each type series has a M. C. Z. catalog number. This number was duplicated on all the lectotype and lectoparatype labels. The species considered in this paper are arranged alphabetically under their respective subfamilies for systematic convenience. The most recent generic assignment for each species is given in brackets after the date. It is my intent to treat the species under consideration more fully in subsequent revisionary studies.

Subfamily Acanthaclisinae

Acanthaclisis hageni Banks 1899. (*Paranthaclisis*)

Lectotype — Phoenix, Arizona (♂). Lectoparatypes — same data (1 ♂, 1 ♀). The lectotype has a red "paratype" label. The female has a red "type" label, the other male has a red "paratype" label. M.C.Z. #10592.

Acanthaclisis texana Hagen 1887. (*Vella*)

Lectotype — Carrizo Springs, Dimmit Co., Texas (♂). Lectoparatypes — same data (2 ♀ ♀). All three specimens have red "type" labels. M.C.Z. #10501.

Subfamily Macronemurinae

Glenopsis peterseni Banks 1922. (*Glenopsis*)

Lectotype — Chanchamayo, Peru (♀ — November). Lectoparatypes — same data (2 ♀ ♀). All three specimens have red "type" labels. M.C.Z. #12044.

Psammoleon minor Banks 1927. (*Psammoleon*)

Lectotype — Dry Tortugas, Loggerhead Key, Florida (♀ — June, 1917, H. L. Clark). Lectoparatype — same data (♂ — June, J. McClendon). I have

selected the female as the lectotype because the male is in poor condition.
M.C.Z. #15746.

Subfamily Dendroleoninae

Austroleon compar Banks 1909. (*Austroleon*)
Lectotype — Pedregal, Argentina, Jensen-Haarup Expedition (♂ —
December 17, 1906). Lectoparatypes — same data (1 ♂, 1 ♀ — January 22,
1907); Mendoza, Argentina (1 ♀). The lectotype has a red "paratype" label.
The female from Pedregal has a red "type" label. M.C.Z. #10601.

Austroleon dispar Banks 1909. (*Austroleon*)
Lectotype — Pedregal, Argentina (♀ — February 27, 1907). Lectoparatypes
— same data (1 ♀ — January 30, 1907); Mendoza, Argentina (1 ♀). The lecto-
type has a red "type" label. M.C.Z. #10600.

Austroleon dorsalis Banks 1910. (*Austroleon*)
Lectotype — Mendoza, Argentina, Jensen-Haarup Expedition (♀). Lecto-
paratypes — same data (5 ♀ ♀). The lectotype has a red "type" label. M.C.Z.
#10603.

Austroleon frontalis Banks 1910. (*Austroleon*)
Lectotype — Mendoza, Argentina, Jensen-Haarup Expedition (♂). Lecto-
paratypes — same data (1 ♂, 4 ♀ ♀). One female has a red "type" label.
M.C.Z. #10604.

Austroleon verticalis Banks 1910. (*Brachynemurus*)
Lectotype — Mendoza, Argentina, Jensen-Haarup Expedition (♀). Lecto-
paratypes — same data (3 ♀ ♀). The lectotype has a red "type" label. M.C.Z.
#10602.

Brachynemurus argentinus Banks 1910. (*Brachynemurus*) ·
Lectotype — Mendoza, Argentina, Jensen-Haarup Expedition (♂). Lecto-
paratypes — same data (2 ♀ ♀). The lectotype has a red "type" label. M.C.Z.
#10614.

Brachynemurus assimilis Banks 1903. (*Hesperoleon*)
Lectotype — Tehama, California (♂ — August 28, 1897). Lectoparatypes
— same data (♂ — August 1897, ♀ — August 28, 1897). M.C.Z. #10578.

Brachynemurus californicus Banks 1895. (*Calinemurus*)
Lectotype — San José del Cabo, Baja California (♂ — September). Lecto-
paratypes — same data (♀); San Lazaro, Baja California (1 ♀). The San Lazaro
specimen has a red "type" label. M.C.Z. #10623.

Brachynemurus carolinus Banks 1911. (*Netroneurus*)
Lectotype — Southern Pines, North Carolina (♀ — June 8, A. H. Manee).
Lectoparatypes — same data (2 ♀ ♀ — June 11, 20, A. H. Manee). The lecto-
type has a red "type" label. The other two females have red "paratype" labels.
M.C.Z. #10575.

Brachynemurus carrizonus Hagen 1888. (*Hesperoleon*)
Lectotype — Carrizo Springs, Dimmit Co., Texas (♂). Lectoparatypes —
same data (2 ♂ ♂, 2 ♀ ♀). Four specimens including the lectotype have red
"type" labels. M.C.Z. #10511.

Brachynemurus dissimilis Manks 1903. (*Hesperoleon*)
Lectotype — San José del Cabo, Baja California (♂ — September). Lecto-
paratypes — same data (2 ♂ ♂, 2 ♀ ♀). The lectotype has a red "paratype" label.

One female has a red "type" label, the other specimens have red "paratype" labels. M.C.Z. #10611.

Brachynemurus eiseni Banks 1908. (*Hesperoleon*)

Lectotype — San José del Cabo, Baja California (♂ — September). Lectoparatypes — same data (1 ♂, 4 ♀). The lectotype has a red "type" label. The other specimens have red "paratype" labels. M.C.Z. #10609.

Brachynemurus elongatus Banks 1904. (*Brachynemurus*)

Lectotype — Mesilla, New Mexico (♂ — June 30, 1897). Lectoparatype — same data (♂). The lectotype has a red "type" label. M.C.Z. #10576.

Brachynemurus fenestratus Banks 1913. (*Brachynemurus*)

Lectotype — Turricares, Costa Rica (♂ — December, Tristan). Lectoparatypes — same data (4 ♂ ♂, 1 ♀). The lectotype has a red "type" label. The other specimens have red "paratype" labels. M.C.Z. #10610.

Brachynemurus fraternus Banks 1895. (*Calinemurus*)

Lectotype — San José del Cabo, Baja California (♂). Lectoparatypes — same data (1 ♀); San Lazaro, Baja California (1 ♂, 1 ♀ — September). The lectotype has a red "paratype" label. The female from San Lazaro has a red "type" label, the other specimens have red "paratype" labels. M.C.Z. #10624.

Brachynemurus longipalpis Hagen 1866. (*Hesperoleon*)

Lectotype — Cape San Lucas, Baja California (♂ — 1860, Xanthus). Lectoparatypes — same data (2 ♂ ♂, 1 ♀); Humboldt Station, Nevada (2 ♂ ♂ — July 29, O. Sacken). Banks indicated in 1927 that the Baja California specimens should be the types. All the specimens have red "type" labels. M.C.Z. #10513.

Brachynemurus minusculus Banks 1899. (*Hesperoleon*)

Lectotype — Lancaster, California (♂ — July). Lectoparatypes — same data (2 ♀ ♀). The lectotype has a red "type" label. The two females have red "paratype" labels. M.C.Z. #10579.

Brachynemurus mexicanus Banks 1895. (*Hesperoleon*)

Lectotype — Tepic, México (♀). Lectoparatypes — same data (1 ♂, 1 ♀). The male lacks an abdomen. Therefore I have selected a female as the lectotype. It has a red "type" label. M.C.Z. #10608.

Brachynemurus nigrilabris Hagen 1888. (*Hesperoleon*) ,

Lectotype — Manitou, Colorado (♀). Lectoparatypes — Farmington, Utah (1 ♀ — July 25); Ogden, Utah (1 ♀ — August 2, O. Sacken); Custer Co., South Dakota (1 ♀ — 1881, Gormen). Banks selected the lectotype in his 1927 paper. All four specimens have red "type" labels. M.C.Z. #10509.

Brachynemurus peregrinus Hagen 1861. (*Hesperoleon*)

Lectotype — Havilah, California (♀). Lectoparatypes — Pecos River, Western Texas (now New Mexico) (2 ♀ ♀). All three specimens have red "type" labels. Banks selected the lectotype in his 1927 paper. Two species are represented in the syntype series. Banks' lectoparatypes are conspecific with *Hesperoleon carrizonus* Hagen. His lectotype is apparently the same species as *Hesperoleon ferox* (Walker). M.C.Z.#10508.

Brachynemurus sackeni Hagen 1888. (*Hesperoleon*)

Lectotype — Dallas, Texas (♀ — Boll). Lectoparatypes — Texas (2 ♂ ♂, 2 ♀ ♀ — Boll); San Francisco, California (1 ♂ — Osten Sacken); California (3 ♂ ♂ — Austin). All of the specimens, except the lectotype, have red "type" labels.

The four specimens from Texas, collected by Boll, are undoubtedly also from Dallas. In his original description, Hagen stated that the Texas material collected by Boll were from Dallas. I am sure that these specimens, which have Hagen labels, were part of his type series and that only the lectotype was fully labeled. Banks indicated in 1927 that the type locality should be Dallas. M.C.Z. #10512.

Brachynemurus strigosus Banks 1909. (*Brachynemurus*)
Lectotype — Pedregal, Argentina (♂ — January 15, 1906). Lectoparatype — Mendoza, Argentina (1 ♀). M.C.Z. #10613.

Brachynemurus tenuis Banks 1898. (*Hesperoleon*)
Lectotype — Mesilla, New Mexico (♂ — June 28, 1897). Lectoparatypes — same data (1 ♂, 4 ♀ ♀). One female has a red "type" label. M.C.Z. #10581.

Calinemurus fuscus Banks 1905. (*Calinemurus*)
Lectotype — Nogales, Arizona (♂ — July 6, 1903, Oslar). Lectoparatype — same data (♂ — July 30, 1903, Oslar). The lectotype has a red "type" label. The lectoparatype has a red "paratype" label. M.C.Z. #10584.

Hesperoleon douglasi Banks 1927. (*Hesperoleon*)
Lectotype — Nogales, Arizona (♂ — July 6, 1903, Oslar). Lectoparatypes — same data (♂ — July 27, 1903, Oslar); Florence, Arizona (3 ♀ ♀ — October 6, 7, 1903); Phoenix, Arizona (15 ♂ ♂, 9 ♀ ♀ — July, August, and September); St. George, Utah (6 ♀ ♀ — June 6, T. Spalding); Coronado, California (1 ♂ — July 24, 1897, A. Morse). Banks indicated in 1927 that the type locality should be Nogales, Arizona. All the specimens have red "type" labels. M.C.Z. #10578.

Hesperoleon hubbardi curtus Banks 1927 (as variety). (*Hesperoleon*)
Lectotype — Seward Co., Kansas (♂ — August 18, 1911, F. X. Williams). Lectoparatype — Boulder, Colorado (1 ♂ — October 20, 1902, Oslar). M.C.Z. #15747.

Hesperoleon tripunctatus Banks 1922. (*Austroleon*)
Lectotype — Palmerlee, Arizona (♂ — June). Lectoparatype — same data (1 ♂ — July). Both specimens have red "type" labels. M.C.Z. #12043.

Maracanda signata Hagen 1887. (*Cryptoleon*)
Lectotype — Whitefish Point, Lake Superior, Michigan (♀). Lectoparatypes — Lundington, Michigan (1 ♂, 1 ♀ — Pierce). All three specimens have red "type" labels. Banks selected the lectotype in his 1927 paper. M.C.Z. #10505.

Microleon apicalis Banks 1901. (*Mimoleon*)
Lectotype — Durango, México (♂). Lectoparatype — same data (♀). M.C.Z. #10627.

Summary
Lectotype designations for thirty species of ant-lions described by Banks and Hagen have been made for the collection at the Museum of Comparative Zoology, Harvard University. Also, the previous designation of three lectotypes by Banks has been clarified.

Acknowledgments

Reference
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A Note on Oviposition and Larval Habits of the Milkweed Beetle, Tetraopes tetrophthalmus Forst. (Coleoptera: Cerambycidae)[1]

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The stout, red-and-black adults of the milkweed beetle are common during June and July on the leaves and flowers of *Asclepias* spp. over most of the range of these plants. It has long been known that the larvae inhabit the soil, feeding on the roots of the host. Craighead (1923) found larval galleries extending from root to root in the soil, and upwards to immediately below the soil surface, where pupation occurs. My own observations corroborate Craighead's; larvae were found in the soil feeding on the outside of the milkweed roots. Thus the larvae are free-living, terricolous insects, much like white grubs.

The above observations on larval habits raised speculation as to the method of oviposition. The milkweed beetle belongs to the subfamily Lamiinae, species of which generally oviposit in their host plants through slits made with the mandibles. Although the habit of ovipositing in the soil is fairly common in the Prioninae, it is known in only one lamiine genus, *Dorcadion* Dalman (Duffy, 1953), and in no other cerambycid subfamilies. Furthermore, close observation of the milkweed beetle in the field and in cages during two seasons failed to reveal any instance of oviposition in the soil or in any part of living milkweed plants.

In 1960, it was eventually found that reconciliation of lamiine-type oviposition habits with the larval habitat of this insect is achieved in a rather unusual manner. On July 21, near Midhurst, Ontario, females of *T. tetrophthalmus* were discovered laying eggs in small (4 mm. diam.), dry, hollow milkweed stubs from the previous year. A very small hole was chewed in the stub, and from one to more than 12 elongate, white eggs were deposited within the hollow interior, where they adhered to the wall (Fig. 1). Further searching disclosed that eggs were also laid in the dead, hollow stems of certain grasses. In these, the diameter of the hollow was only slightly greater than the width of the eggs (0.43 mm.). Usually several holes were made at intervals along each stem used, and one or two eggs deposited through each hole (Fig. 2).

Following these observations, adult beetles were caged over soil into which milkweed plants with dead stubs and a clump of grass with dead stems had been transplanted. Oviposition occurred as observed in the field, and the cage was kept under observation to determine how the larvae eventually reach the soil from the oviposition site.

The eggs hatched in from six to ten days, and, soon after hatching, the young larvae left the stems and stubs by enlarging the oviposition holes and falling freely to the ground. No feeding took place on the dry stems. Larvae caught in glass dishes placed on the soil surface below overhanging stems were identified as first-instar larvae. Larval drop occurred during the cool of evening, which would minimize the danger of desiccation to the tiny (2.3 mm. long) larvae. Though not observed, it is possible that some larvae in milkweed stubs may have reached the soil by falling or crawling down the hollow interior, which is unobstructed.

Quentin (1951) described oviposition in dead grass by *Dorcadion fuliginator* L., but although he implied that the larvae leave the stem after hatching, he apparently did not observe the manner of leaving. Oviposition by *D. fuliginator* took place only below the first node of the stem, which suggests that the larvae may enter the soil by going down the interior. In contrast, *T. tetrophthalmus*
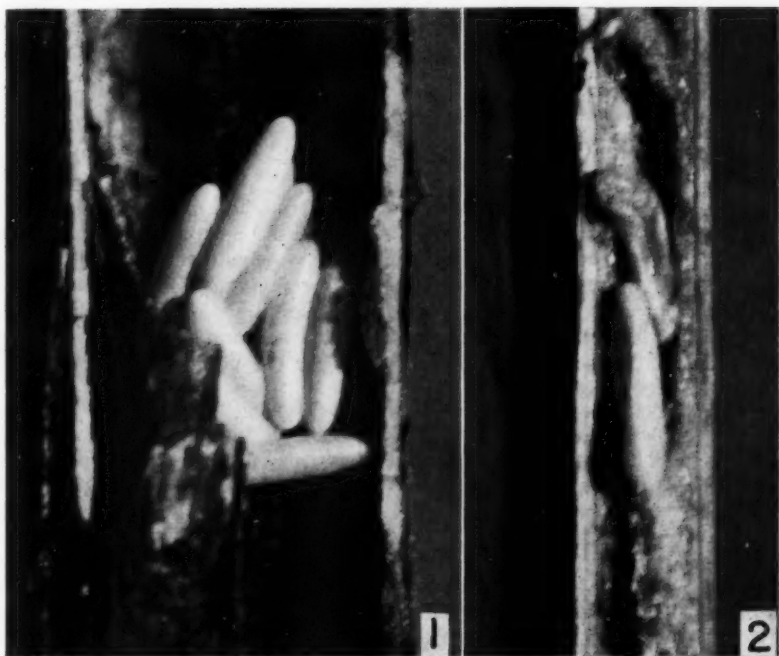
Figs. 1, 2. Eggs of *T. tetrophthalmus*. 1, Deposited in year-old milkweed stub. 2, Deposited in dead grass stem; eggs damaged when stem dissected.

oviposits wherever the stem is thick enough, and frequently in excess of 40 cm. above ground in tall grass.

Although legless, the first-instar larvae appear capable of moving over distances of several feet; they are very active, and survived for four days in a glass dish without food or water. Oddly, they seem unable to crawl normally, but only move on their backs, the dorsal surface being well armed with spicules and so-called "egg-bursting spines". It is not known whether the larvae are able to utilize the roots of grasses or other plants as food before reaching the roots of milkweed plants.

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(Received January 24, 1961)

Variation Between Samples of Fruit, and of Fruit Damages Mainly from Insect Pests, on Apple in Quebec

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In May, 1958, studies on the distribution of fruit, and of fruit damages from all sources, were initiated in permanent apple orchard plots at Rougemont, Que. The object was to develop sound sampling techniques to determine, within error limits, damages to the fruit resulting from the feeding activities of orchard insect pests, and from mechanical causes, during the period apple set in early June to harvest in mid September. This is a report on variation in samples of apples, and of damages to the fruit from all sources, for the years 1958 and 1959, and on sampling recommendations.

Sampling

Sampling of fruit and fruit damages was carried out in experimental plot "A", Cistercian Fathers' apple orchard, Rougemont, Que. A description of the plot was given in a previous paper by LeRoux and Reimer (1959).

Unit

The sample unit most suitable in the study of fruit and fruit damages from all sources, on McIntosh apple trees, is the leaf cluster. This unit of foliage is relatively stable for mature McIntosh trees and on it are found the fruit produced by the tree. The mean number of leaf clusters per tree for 35-year old trees sampled was $11,300 \pm 800$, and the mean number of leaves per cluster 11.2 ± 0.2. The numbers of clusters per tree and of leaves per cluster did not vary significantly during the growing seasons of 1958 and 1959.

Procedure

To determine the distributions of the fruit, and fruit damages from all sources, within the crown of the tree, and to compare variation between trees with that within trees, the plot was divided into four equal blocks, L, M, N, O. Five trees selected at random were sampled per block. Each tree crown was divided horizontally into halves designated A, the top, and B, the bottom. Each half was divided into four equal quadrants, N, S, E, and W, according to the four cardinal points of the compass. This provided for eight sampling sections within the tree crown, namely, NA, SA, etc. From each section 25 leaf clusters were collected and the number of apples and the types of fruit damages were recorded and the data subjected to an analysis of variance.

Timing

Fruit and fruit damages were sampled eight times during each growing season, i.e., in early and late June, early, mid, and late July, early and mid August, and in mid September, for a total of 16 samplings during the two years of study. Damages to the apples were recorded for the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), the fruit-tree leafroller, *Archips argyrospilus* (Wlkr.), the plum curculio, *Conotrachelus nenuphar* (Hbst.), and the codling moth, *Carpocapsa pomonella* (L.). Mechanical injury to the fruit from hail was recorded in 1958 only. The pistol casebearer, *Coleophora serratella* (L.), at present under intensive study in plot 'A', was not observed to damage the fruit during the period of study. Damages observed were for the bud moth, light

TABLE I

Analysis of variance of total apples, 1958 apple crop (Table IV, first sampling, early June, total)

Source of variation	Expected mean square[1]	d.f.	Observed mean square	F
Between trees				
Blocks	$\sigma^2 s + 8\sigma^2 t + 40\ \sigma^2 b$	3	56.6	1.0
Trees within blocks	$\sigma^2 s + 8\sigma^2 t$	16	64.7	3.9[2]
Within trees				
Levels	$\sigma^2 s + 80\sigma^2 l$	1	4.2	
Quadrants	$\sigma^2 s + 40\sigma^2 q$	3	9.4	
LxQ	$\sigma^2 s + 20\sigma^2 l q$	3	9.1	
Residual	$\sigma^2 s$	133	16.4	

[1] $\sigma^2 s$, $\sigma^2 t$, etc., are crop parameters; S^2_s, S^2_t, in the text are estimates of these parameters.
[2] Significant at the one per cent level.

irregular scarring of the fruit surface by the larvae in the immediate vicinity of the larval leaf shelter; by the fruit-tree leafroller, a pronounced and regular scarring of the fruit surface by the larvae or deep feeding within the young fruit near the larval leaf shelter; by the plum curculio, light semi-circular egg-laying scars or deeper irregular feeding scars on the surface of the fruit by the adults or larval feeding within the apples; by the codling moth, light or deep penetration into the fruit by the larvae with much brown frass. Hail damages resulted in light and deep wounds of various sizes to the fruit which darkened shortly after injury.

Methods of Statistical Analysis

An analysis of variance was made of all counts without transformation for the reasons expressed by LeRoux and Reimer (1959). In the present study, the density range was considered to be sufficiently low for direct analysis. For individual samplings, the inter-tree range of densities was less than twenty-five-fold.

The analysis of variance is illustrated in Table I with one of the sets of data. The procedure for obtaining the expected mean squares may be found in a number of statistical books (e.g. Bennett and Franklin, 1954, Secs. 7.53, 7.62, 7.63). Since the expected values are based on the assumption, among others, that the effects of trees, crown levels, etc., on total fruit and fruit damages are additive, they can only be regarded as approximations. They are tabulated here to indicate how each component of variance can be tested for significance and how an estimate of it can be calculated.

All mean squares except that for blocks have only one component of variance in addition to the intra-tree error variance σs^2; the latter is therefore the appropriate denominator in all their F ratios. As the mean square for blocks contains inter-tree error variance, σt^2, as well as σs^2, its F ratio has the mean square for trees in the denominator, i.e., $F = 56.6/64.7$, which has 3 and 16 degrees of freedom and is not significant.

Sources of Variation

In the mathematical model from which the expected mean squares (Table I) are deduced, differences between blocks, between crown levels, and between quadrants are regarded as systematic errors, and differences between trees and between clusters as random errors. The effect of random errors on the estimate of mean density can be controlled by the amount of sampling, i.e., by the number of trees and the number of clusters per tree that are examined. The effect of

systematic errors can be eliminated only by taking the samples in such a way
that all gradients of density, e.g., between crown levels are represented in the
sample in proportion to the amount of foliage.

Differences in the number of fruit, and fruit damaged from all sources, re-
ported in the following sections were statistically significant unless otherwise
stated (Tables II and III). Sources of variation for insect and mechanical
damages (1958 only) are reported in the order in which these appeared on the
fruit during the growing seasons, 1958 and 1959.

Total apples

Differences between trees in total number of apples were consistent for all
samplings in 1958 and 1959. Total apples differed between levels in all samplings
except 1st and 2nd samplings, 1958, and 1st, and 4th to 6th samplings, 1959. For
these differences, ratios in the upper to that in the lower crown level ranged
from 1.1 to 1.4 (except for a ratio of 0.79 4th sampling), 1958, and from 0.54
to 0.76, 1959. This was due to the greater concentration of fruit in the upper
crown level in 1958 and in the lower crown level in 1959. Totals did not differ
between quadrants except for 3rd sampling, 1958, and 4th sampling, 1959. This
was also true for interactions between levels and quadrants which differed statis-
tically in the 4th sampling only, 1959. Total fruit differences between blocks
were not significant except for 7th sampling, 1958, and 3rd, 4th, and 8th samplings,
1959. For all other samplings, total fruit differences were not significant.

Undamaged apples

There were tree differences between total apples undamaged for all
samplings, 1958 and 1959. No differences between blocks were found except
for 6th sampling, 1958, and 3rd and 4th samplings, 1959. There were level
differences for the 4th to 8th samplings, 1958, and 2nd, 3rd, and 8th samplings,
1959. For these samplings, ratios in the upper to that in the lower crown level
were greater than *one* in 1958 and less than *one* in 1959, indicating that more
clean fruit was present in the upper crown level in 1958, and more in the lower
crown level in 1959. There were no quadrant differences except for the 2nd
and 4th samplings, 1959, and no interaction differences between levels and
quadrants except for the 4th sampling, 1959. For all other samplings, differences
between total clean fruit were not statistically significant.

Damaged apples

Total.—There were differences between trees for total fruit damaged from
all sources for the 1st, 5th, and 7th samplings, 1958, and 1st, 2nd, 4th, and 6th
samplings, 1959. For all other samplings, fruit damages between trees were
not statistically significant. No differences between blocks were found except
for 2nd sampling, 1959. Total crop damages differed between levels for the
2nd, 4th, and 8th samplings, 1958, and 2nd, 6th, 7th, and 8th samplings, 1959.
For these samplings crop damages were consistently greater in the lower crown
level. There were no quadrant differences, save for the 5th sampling, 1958, and
no significant interaction between levels and quadrants, save for the 6th sampling,
1959.

A. argyrospilus.—Crop damages by this species were recorded in all eight
samplings, 1958, and 1959, although larval feeding on the fruit is restricted
largely to the month of June. A high proportion of the damaged apples do not
drop from the trees in June and are included in subsequent counts.

There were differences between trees for apples damaged by *A. argyrospilus*
in the 1st sampling only, 1958, and in the 1st, 2nd, 6th, and 7th samplings, 1959.

TABLE II

Significance of variation due to blocks, trees, levels, quadrants, levels x quadrants, between samples of apples and apple damages from five sources, 1958, a sample of 25-leaf clusters being taken from each of eight sections from each of 20 trees.

Samplings	Blocks	Trees	Levels (Ratio A/B)	Quadrants	Levels x Quadrants
GROWING SEASON, 1958					
1st sampling, early June					
Undamaged	—	xx	—	—	—
Damaged—F. T. Leafroller	—	xx	—	—	—
Total	—	xx	—	—	—
2nd sampling, late June					
Undamaged	—	xx	—	—	—
Damaged	—	—	0.9xx	—	—
F.T. Leafroller	—	—	0.6xx	—	—
Plum curculio	—	xx	—	—	—
Total	—	x	—	—	—
3rd sampling, early July					
Undamaged	—	xx	—	—	—
Damaged	—	—	—	—	x
F.T. Leafroller	—	—	0.6x	—	xx
Plum curculio	xx	—	—	—	—
Total	—	xx	—	x	—
4th sampling, mid July					
Undamaged	—	xx	0.8x	—	—
Damaged	—	—	0.7x	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	0.45x	x	—
Codling moth	—	—	—	—	—
Total	—	xx	0.79x	—	—
5th sampling. late July					
Undamaged	—	xx	1.1x	—	—
Damaged	—	x	—	x	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	xx	—	—	x	—
Codling moth	—	—	—	—	—
Hail	—	—	2.0x	—	—
Total	—	xx	1.1x	—	—
6th sampling, early August					
Undamaged	x	x	1.8x	—	—
Damaged	—	—	—	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	—	—	xx
Codling moth	x	xx	—	—	x
Hail	—	x	—	—	—
Bud moth	—	xx	—	—	—
Total	—	xx	1.4xx	—	—
7th sampling, mid August					
Undamaged	—	xx	1.8xx	—	—
Damaged	—	x	—	—	—
F.T. Leafroller	—	—	0.6x	—	—
Plum curculio	—	—	—	x	—
Codling moth	—	—	—	—	—
Hail	xx	—	—	—	—
Bud moth	—	—	—	—	—
Total	xx	xx	1.3xx	—	—
8th sampling. mid September					
Undamaged	—	xx	2.5xx	—	—
Damaged	—	—	0.7x	—	—
F.T. Leafroller	—	—	0.6x	—	—
Plum curculio	—	—	—	—	—
Codling moth	—	—	—	—	—
Hail	—	xx	—	—	—
Bud moth	—	—	—	—	—
Total	—	xx	1.4xx	—	—

TABLE III

Significance of variation due to blocks, trees, levels, quadrants, levels x quadrants, between samples of apples and apple damages from four sources, 1959, a sample of 25-leaf clusters being taken from each of eight sections from each of 20 trees.

Samplings	Blocks	Trees	Levels (Ratio A/B)	Quadrants	Levels x Quadrants
GROWING SEASON, 1959					
1st sampling, early June					
Undamaged	—	xx	—	—	—
Damaged—F.T. Leafroller	—	xx	—	—	—
Total	—	xx	—	—	—
2nd sampling, late June					
Undamaged	—	xx	0.72xx	xx	—
Damaged	xx	xx	0.36x	—	—
F.T. Leafroller	—	xx	0.35x	—	x
Plum curculio	—	—	—	—	—
Total	—	xx	0.68xx	x	—
3rd sampling, early July					
Undamaged	x	xx	0.62xx	—	—
Damaged	—	—	—	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	—	—	—
Total	x	xx	0.61xx	—	—
4th sampling, mid July					
Undamaged	xx	xx	—	x	x
Damaged	—	x	—	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	—	—	—
Codling moth	—	—	—	—	—
Total	xx	xx	—	x	x
5th sampling, late July					
Undamaged	—	xx	—	—	—
Damaged	—	—	—	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	0.01x	—	—
Codling moth	—	xx	—	—	x
Bud moth	—	—	—	—	—
Total	—	xx	—	—	—
6th sampling, early August					
Undamaged	—	xx	—	—	—
Damaged	—	xx	0.57x	xx	—
F.T. Leafroller	—	xx	—	—	—
Plum curculio	—	—	—	x	—
Codling moth	—	—	—	—	—
Total	—	xx	—	—	—
7th sampling, mid August					
Undamaged	—	xx	—	—	—
Damaged	—	—	0.35xx	—	—
F.T. Leafroller	—	x	0.47x	—	x
Plum curculio	—	—	—	—	x
Codling moth	x	—	0.16x	—	—
Bud moth	—	—	—	—	—
Total	—	xx	0.76x	—	—
8th sampling, mid September					
Undamaged	—	xx	0.67xx	—	—
Damaged	—	—	0.30x	—	—
F.T. Leafroller	—	—	—	—	—
Plum curculio	—	—	0.10xx	—	—
Codling moth	—	—	—	—	—
Bud moth	—	—	—	—	—
Total	—	xx	0.54xx	—	—

No differences between blocks were found in either years. Level differences were recorded for the 3rd sampling only, 1958, and for the 2nd and 7th samplings, 1958 and 1959. For these samplings, ratios in the upper to that in the lower crown level were less than *one* for both 1958 and 1959, indicating that larvae of *A. argyrospilus* fed in greater numbers in the lower crown level. No differences between quadrants were found except for 3rd and 2nd samplings, 1958 and 1959, respectively. Interactions between levels and quadrants were not significant except for 7th sampling, 1959.

C. nenuphar.—Damages to the fruit by *C. nenuphar* were first observed in the samples in late June, 1958 and 1959, at the time of 2nd sampling. Because of the feeding activities of this species during the remainder of the growing season, fruit damages were recorded in all subsequent samplings.

There were no differences between trees in the number of fruit damaged by this pest except for 2nd sampling, 1958, and no differences between blocks except for the 3rd and 5th samplings, 1958. There were differences between levels in the 4th samplings, 1958 and 1959, and in the 8th sampling only, 1959. For these samplings ratios in the upper to that in the lower crown levels were less than *one* indicating a greater damage to the fruit by *C. nenuphar* in the lower crown level. Differences between quadrants occurred in the 4th, 5th and 7th samplings, 1959a), and were supplemented in future samplings by the entry of larvae of the quadrants were significant in the 6th sampling, 1958 and 7th sampling, 1959, only.

C. pomonella.—Damages to the fruit by the codling moth were first observed in mid July, 1958 and 1959, at the time of the fourth samplings. These damages coincided with the appearance of first-generation larvae in the fruit (LeRoux, 1959), and were supplemented in future samplings by the entry of larvae of the second generation which appeared in mid August (LeRoux, 1959b). Damages by this species were recorded in all samplings beginning with the 4th sampling.

There were differences between trees, and between blocks in the 6th sampling, 1958, and in the 5th and 7th samplings, 1959, respectively. There were no level differences except for 7th sampling, 1959, and for this sampling the ratio of the upper to that in the lower crown level of the tree was less than *one* showing *C. pomonella* damages to be greater in the lower crown level. No differences between quadrants were found in either year, and only two level by quadrant interactions were statistically significant, i.e., 6th sampling, 1958, and 5th sampling, 1959.

S. ocellana.—Fruit damages by the eye-spotted bud moth were first recorded in early August, 6th sampling, 1958, and in late July, 5th sampling, 1959 and resulted from the feeding activities of summer larvae (LeRoux and Reimer, 1959). Damages by this species were recorded for all remaining samplings. Fruit damages by spring larvae, present in late May and early June were not observed during the two-year period of study.

There were tree differences, 6th sampling only, 1958. For all other samplings, 1958 and 1959, differences between trees, blocks, levels, quadrants, and levels by quadrants were not statistically significant. The lack of level differences was particularly surprising since an associated study (LeRoux and Reimer, 1959) revealed populations of summer larvae of the budmoth, during period 1956 to 1959 to be almost consistently greater in upper crown levels of apple trees.

Hail.—In late July 1958, at the time of 5th sampling, a sudden hail storm resulted in considerable mechanical damage to the crop in plot 'A'. For the resulting damages recorded from the 5th to 8th samplings, there were differences between trees in the 6th and 7th samplings, between blocks in th 7th and 8th

samplings, and between levels in the 5th sampling only. Level differences were significant in this count which was the first taken after the hail storm when all or nearly all damaged apples were still on the tree. For this sampling the ratio of the upper to that in the lower crown level was greater than *one* indicating that the upper crown level is the area most vulnerable to mechanical injury by the falling hail stones. This was partly a result of the heavier apple crop in the upper crown level of the trees in 1958. Differences between quadrants and levels, and interactions between levels and quadrants were not statistically significant. Seventy-two per cent of the apples damaged by hail were still on the tree at the last sampling (Table IV, 5th to 8th samplings).

Differences important in sampling

The analyses of variance indicated that for the sampling of total crop, differences between crown levels must be taken into account and therefore the entire height of the tree should be represented in the samples. The number of leaf clusters examined for fruit at each level should be roughly proportional to the amount of foliage in that level. Although appreciable differences between quadrants were found in only a few samplings (Table III, 2nd and 4th samplings, 1959), it is strongly recommended that all quadrants be sampled if absolute values for crop, and crop damages from all sources are desired. Again the number of leaf clusters sampled should be proportional to the amount of foliage. On the basis of the analysis of variance, these recommendations also apply when sampling total clean crop or total crop damages from all sources.

To sample for crop damages resulting from the feeding activities of individual insect pest species reported in this study, the above sampling recommendations apply for *A. argyrospilus*, *C. nenuphar*, and *C. pomonella*. For *S. ocellana*, at population densities and crop levels similar to those reported here, only the lower crown level should be sampled.

Components of Variance

After the F tests have sorted out those factors that made a demonstrable contribution to the over-all variation from those that did not, it is sometimes useful to estimate the magnitudes of some of the contributions. In this study, as in a previous study (LeRoux and Reimer, 1959), estimates of the intra-tree (S_s^2) and inter-tree (S_t^2) error variances were calculated and used to determine the optimum number of samples per tree and also the number of trees required to obtain an estimate of the density of the crop and of crop damages from all sources with a specified standard error.

The inter-tree variance was obtained from the mean square for trees and the residual mean square by the formula $(MST - MSR) \div 8$; it was assumed to be zero whenever MST was not significant. For example, from the mean squares in Table I, $S_t^2 = (64.7 - 16.4) \div 8 = 6.04$, and $S_s^2 = 16.4$. These components of variance for all samplings are listed in Tables IV and V.

This summarizes the results of the analyses of variance, which can now be applied (a) to determine the reproducibility of the present crop and crop damages estimates, and (b), to make sampling recommendations for sampling procedures in intensive studies of insect pest and crop interrelationships.

Estimates of the mean number of apples and of apples damaged from all sources for all samplings are listed in Tables IV and V along with their standard errors. Each mean represents observations on eight samples of 25 leaf clusters from each of 20 trees. Standard errors were computed from the mean squares for trees by the formula $S_x = \sqrt{MST/160}$, except for those cases in which trees

TABLE IV

Estimates of mean densities and of variation between samples of apples and apple damages from five sources, 1958, a sample of 25-leaf clusters being taken from each of eight sections from each of 20 trees.

Samplings	Mean number per sample, $\bar{x}$	Variance components		
		Within trees, S_a^2	Between trees, S_t^2	Ratio S_a^2/S_t^2
GROWING SEASON, 1958				
1st sampling, early June				
Undamaged	6.25±0.5	13.8	4.33	3.19
Damaged—F.T. Leafroller	1.23±0.1	1.21	0.27	4.48
Total	7.48±0.6	16.4	6.03	2.72
2nd sampling, late June				
Undamaged	5.87±0.4	12.0	2.06	5.82
Damaged	2.59±0.2	5.67	0.16	35.44
F.T. Leafroller	2.23±0.2	3.68	0.0	0.0
Plum curculio	0.36±0.1	0.77	0.19	4.05
Total	8.46±0.5	22.3	1.92	11.61
3rd sampling, early July				
Undamaged	4.51±0.3	6.57	1.18	5.57
Damaged	1.21±0.1	1.72	0.09	19.11
F.T. Leafroller	0.96±0.1	1.42	0.08	17.75
Plum curculio	0.25±0.05	0.35	0.0	0.0
Total	5.72±0.39	8.86	2.06	4.30
4th sampling, mid July				
Undamaged	3.70±0.2	4.81	0.77	6.25
Damaged	0.98±0.09	0.91	0.06	15.2
F.T. Leafroller	0.67±0.07	0.63	0.02	31.5
Plum curculio	0.20±0.04	0.22	0.01	22.0
Codling moth	0.11±0.03	0.11	0.01	11.0
Total	4.68±0.3	7.74	1.33	5.82
5th sampling, late July				
Undamaged	4.13±0.3	4.22*	1.25	3.38
Damaged	1.45±0.1	1.46	0.16	9.13
F.T. Leafroller	0.77±0.07	0.72	0.01	72.0
Plum curculio	0.10±0.02	0.09	0.0	0.0
Codling moth	0.22±0.05	0.25	0.02	12.5
Hail	0.36±0.06	0.48	0.03	16.0
Total	5.58±0.4	7.85	2.37	3.31
6th sampling, early August				
Undamaged	2.39±0.16	2.45	0.26	9.42
Damaged	1.54±0.1	1.64	0.11	14.9
F.T. Leafroller	0.73±0.7	0.89	0.0	0.0
Plum curculio	0.08±0.02	0.91	0.0	0.0
Codling moth	0.29±0.07	0.32	0.05	6.40
Hail	0.32±0.05	0.26	0.03	8.67
Bud moth	0.12±0.04	0.13	0.02	6.50
Total	3.93±0.25	4.35	0.79	5.51
7th sampling, mid August				
Undamaged	2.29±0.2	2.66	0.51	5.22
Damaged	1.19±0.1	1.16	0.12	9.67
F.T. Leafroller	0.43±0.55	0.35	0.02	17.5
Plum curculio	0.04±0.01	0.04	0.001	40.00
Codling moth	0.20±0.04	0.25	0.0	0.0
Hail	0.34±0.05	0.38	0.0	0.0
Bud moth	0.18±0.04	0.23	0.004	57.50
Total	3.48±0.25	4.25	0.71	5.99
8th sampling, mid September				
Undamaged	1.6 ±0.19	1.50	0.56	2.68
Damaged	1.28±0.1	1.14	0.07	17.51
F.T. Leafroller	0.56±0.06	0.47	0.01	47.0
Plum curulio	0.06±0.02	0.07	0.0	0.0
Codling moth	0.21±0.04	0.25	0.01	25.00
Hail	0.26±0.05	0.21	0.04	5.25
Bud moth	0.10±0.04	0.19	0.01	19.00
Total	2.88±0.24	2.64	0.90	2.94

TABLE V

Estimates of mean densities and of variation between samples of apples and apple damages from four sources, 1959, a sample of 25-leaf clusters being taken from each of eight sections from each of 20 trees.

Samplings	Mean number per sample, $\bar{x}$	Variance components		
		Within trees S^2_s	Between Trees S^2_t	Ratio S^2_s/S^2_t
GROWING SEASON, 1959				
1st sampling, early June				
Undamaged	1.8 ±0.36	3.53	2.24	1.58
Damaged—F.T. Leafroller	0.18±0.05	0.24	0.03	8.00
Total	1.98±0.39	4.56	2.59	1.76
2nd sampling, late June				
Undamaged	1.85±0.33	2.08	2.00	1.04
Damaged	0.16±0.05	0.16	0.03	5.33
F.T. Leafroller	0.12±0.04	0.10	0.02	5.00
Plum curculio	0.04±0.02	0.04	0.002	20.00
Total	2.01±0.37	2.84	2.37	1.20
3rd sampling, early July				
Undamaged	1.76±0.22	1.78	0.83	2.14
Damaged	0.18±0.04	0.17	0.01	17.00
F.T. Leafroller	0.11±0.03	0.09	0.01	9.00
Plum curculio	0.05±0.02	0.05	0.0	0.0
Total	1.93±0.24	1.84	0.95	1.94
4th sampling, mid July				
Undamaged	1.61±0.19	1.43	0.62	2.31
Damaged	0.17±0.04	0.15	0.01	15.00
F.T. Leafroller	0.13±0.03	0.11	0.01	11.0
Plum curculio	0.03±0.02	0.02	0.002	10.0
Codling moth	0.02±0.01	0.02	0.0001	700.0
Total	1.78±0.18	1.46	0.47	3.10
5th sampling, late July				
Undamaged	1.43±0.17	1.19	0.47	2.53
Damaged	0.24±0.01	0.23	0.0	0.0
F.T. Leafroller	0.13±0.03	0.12	0.002	60.0
Plum curculio	0.04±0.18	0.06	0.0	0.0
Codling moth	0.05±0.02	0.04	0.01	4.00
Bud moth	0.03±0.02	0.03	0.002	15.0
Total	1.67±0.19	1.27	0.58	2.19
6th sampling, early August				
Undamaged	1.45±0.19	1.42	0.6	2.36
Damaged	0.41±0.07	0.36	0.06	6.00
F.T. Leafroller	0.14±0.05	0.12	0.04	3.00
Plum curculio	0.03±0.02	0.04	0.0	0.0
Codling moth	0.10±0.04	0.16	0.01	16.00
Bud moth	0.13±0.03	0.15	0.0	0.0
Total	1.86±0.22	0.16	0.84	0.19
7th sampling, mid August				
Undamaged	0.96±0.15	0.80	0.37	2.16
Damaged	0.36±0.05	0.32	0.01	32.00
F.T. Leafroller	0.16±0.02	0.05	0.01	5.00
Plum curculio	0.02±0.01	0.02	0.0	0.0
Codling moth	0.04±0.01	0.04	0.0	0.0
Bud moth	0.14±0.03	0.12	0.01	12.00
Total	1.32±0.20	1.07	0.53	2.02
8th sampling, mid September				
Undamaged	0.74±0.10	0.62	0.13	4.77
Damaged	0.32±0.04	0.32	0.0	0.0
F.T. Leafroller	0.04±0.01	0.04	0.0	0.0
Plum curculio	0.04±0.02	0.04	0.0008	50.00
Codling moth	0.09±0.02	0.10	0.001	100.00
Bud moth	0.15±0.03	0.14	0.01	14.00
Total	1.06±0.13	0.66	0.25	2.64

TABLE VI

Estimation of numbers of 25-cluster samples per tree required to minimize cost of collection and examination of apples and apple damages from all sources.

Samplings	Mean ratio[1] of variance components, S^2_s/S^2_t	Cost ratio[2] C_t/C_s	No. of samples $n = \sqrt{\left(\dfrac{S^2_s}{S^2_t}\right)\left(\dfrac{C_t}{C_s}\right)}$
1st sampling, early June	3.62	0.66	1.54
2nd sampling, late June	9.94	0.66	2.56
3rd sampling, early June	9.60	0.66	3.52
4th sampling, mid July	69.43	0.66	6.77
5th sampling, late July	18.18	0.66	3.47
6th sampling, early August	7.18	0.66	2.18
7th sampling, mid August	17.19	0.66	3.37
8th sampling, mid September	24.23	0.66	3.99

[1] Omitting ratios in which $S^2_t = 0$

[2] C_t, cost of moving from one tree to another and preparing for sampling; C_s, cost of examining one sample.

did not differ significantly; here the residual mean squares were used instead. As the data indicate the standard error for total apples and apples undamaged was generally in the order of 20 per cent of the mean or less, and for apples damaged by insect pests and hail, 25 per cent of the mean or less. For insect damages exceptions were to be noted for *A. argyrospilus*, 1st to 3rd, and 6th and 8th samplings, 1959; *C. nenuphar*, 2nd to 8th samplings, 1959, and 2nd, 7th and 8th samplings, 1958; *C. pomonella*, 3rd sampling, 1958, and 3rd to 7th samplings, 1959; *S. ocellana*, 6th and 5th samplings, 1958 and 1959, respectively. For these samplings, the standard error ranged from 27 to 61 per cent.

Optimum Number of Samples Per Tree

The procedure for determining optimum allocation of resources in two-stage sampling may be found in a number of statistical books (e.g., Cochran, 1953, Sec. 10.6; Snedecor, 1956, Sec. 7.12). In the present study, trees constituted the primary sampling units and the 25-cluster samples were the secondary sampling units. Using the appropriate values in the formula given by Cochran and Snedecor gives the estimated number of samples per tree that will minimize the total cost of collection and examination as $n = \sqrt{(S^2_s/S^2_t)\ (C_t/C_s)}$ where S^2_s and S^2_t are the intra- and inter-tree variance components, C_t is the cost of moving from one tree to another, and C_s is the cost of taking and examining one sample of 25 clusters.

A summary of the calculations leading to n is given in Table VI. The ratios of the variance components, for each category of each sampling for the two years (Tables IV and V) were averaged. For example the average of the variance ratios for 2nd sampling, 1958 and 1959 was 9.94 (Table VI), which value was used to determine n. For this sampling the estimate of S^2_t for damages to the fruit by *A. argyrospilus* was zero. Hence for this category there would be no advantage in allocating the samples to more than one tree. However, instead of assigning an arbitrarily large ratio of variance components to this count, n was calculated from the average of the other ratios which was 9.94 as mentioned above.

For all samplings (i.e., 1st, 2nd, 3rd samplings, etc., 1958 and 1959) the cost ratio, C_t/C_s was identical. For 20 trees the total time required to walk from tree to tree and to prepare for sampling at each tree was about one day for each

sampling or 24 minutes per tree. The time required for two men to examine 160 samples was similarly identical for all samplings and was estimated to be one and one-half days or 36 minutes per tree, i.e., $C_s = 36$. Since $C_t = 24$, the cost ratio of each sampling was 0.66. These cost figures are applicable for each of the sixteen samplings made during the two year study.

On the basis of these calculated n values it is recommended that two 25-cluster samples be examined for 1st sampling, three 25-cluster samples for 2nd, 3rd, and 6th samplings; four for 5th, 7th and 8th samplings; and seven for 4th sampling. Since the standard error is obtained directly from the mean square for trees, it would ordinarily be unnecessary to take the number of samples recommended separately. Instead a single sample of 50, 75, etc., leaf clusters (Table VIII) might be taken; each sample taken in such a way that it represents all crown levels and quadrants.

Number of Trees to be Sampled for a Specified Precision

Estimates of the number of trees n_t, required for a 10 and a 20 per cent standard error of the mean were calculated (Table VII); the first estimate to serve as a guide for more intensive studies of crop and crop damages, the second for less intensive studies. The coefficients of inter-tree variation used to determine n_t are based on integral values of n, the number of 25-cluster samples per tree (Table VII), and were calculated from the components of variance and the means (Tables IV and V), as follows:

$$\text{C.V.}_{\cdot n} = \frac{100}{\bar{x}} \sqrt{\frac{\bar{s}^2_s}{n} + S^2_t}$$

For example, for total apples, 1st sampling, 1958 (Table IV)

$$\text{C.V.}_{\cdot n} = \frac{100}{7.48} \sqrt{\frac{16.4}{2} + 6.03} = 50.4\%$$

The number of trees, n_t, required for a standard error of p per cent may be derived from the coefficient of inter-tree variation as $n_t = (\text{C.V.}_{\cdot n}/p)^2$. For total apples, for example, a total of $(50.4/10)^2$ or 29 trees should be sampled for a 10 per cent error and $(50.4/20)^2$, or 7 trees for a 20 per cent error. In both instances, 50 leaf clusters should be sampled from each tree.

These calculated values of n_t are applicable to orchards that are roughly similar in size and uniformity to the experimental orchard sampled in this study. The orchard should be partitioned into blocks if marked gradients in total crop or in crop damages from insect pests and from mechanical causes are expected. Such marked gradients are usually observed when studies of crop and crop damages cover a period of several years. If block size varies appreciably, the number of trees to be sampled in each should be roughly proportional to the size of the block if the variation is similar in the various blocks.

The above formula for n is appropriate when only a small fraction of all the trees in the orchard are to be sampled. This was the case in the present study. However, if more than one-tenth of all trees are needed to obtain the desired precision a "finite population correction" should be applied (Cochran, 1953, Sec. 2.5 and 4.5; Hansen *et al.*, 1953, Sec. 4.11; Snedecor, 1956, 17.6).

Suggested Sampling Plan

Though the values of n_t were estimated (Table VII) for single variables, what is usually needed in practice is a combined estimate for all variables studied at any one sampling. When more than one variable is studied the usual pro-

TABLE VII

Estimation of numbers of trees to be sampled for a 10 and 20 per cent error, on the basis of n 25-cluster samples, for apples and apple damages from all sources.

Samplings	No. of samples per tree	C.V.$_{,n}$[1]	$n_t{}^2$	
			S.E. 10%	S.E. 20%
1st sampling, early June 1958	2			
Undamaged		53.6	29	7
Damaged—F.T. Leafroller		75.6	57	8
Total		50.4	29	7
1959				
Undamaged		111.1	123	31
Damaged—F.T. Leafroller		216.7	469	117
Total		111.6	124	31
2nd sampling, late June 1958	3			
Undamaged		41.9	17	4
Damaged		55.2	30	7
F.T. Leafroller		49.3	24	6
Plum Curculio		183.3	336	84
Total		36.2	13	3
1959				
Undamaged		88.6	78	19
Damaged		180.6	326	81
F.T. Leafroller		191.7	367	92
Plum Curculio		310.0	961	240
Total		90.5	82	20
3rd sampling, early July 1958	3			
Undamaged		40.6	16	4
Damaged		67.1	45	11
F.T. Leafroller		77.4	60	15
Plum curculio		136.4	186	46
Total		39.2	15	4
1959				
Undamaged		67.6	45	11
Damaged		143.3	205	51
F.T. Leafroller		181.8	330	83
Plum curculio		258.0	665	166
Total		64.7	42	10
4th sampling, mid July 1958	7			
Undamaged		32.7	11	3
Damaged		44.5	20	5
F.T. Leafroller		49.5	24	6
Plum curculio		101.5	103	26
Codling moth		145.4	211	53
Total		33.3	11	3
1959				
Undamaged		56.4	32	8
Damaged		104.1	108	27
F.T. Leafroller		123.1	151	38
Plum curculio		232.3	539	135
Codling moth		270.0	729	182
Total		46.1	21	5
5th sampling, late July 1958	4			
Undamaged		36.8	13	3
Damaged		50.0	25	6
F.T. Leafroller		55.8	31	8
Plum curculio		150.0	225	56
Codling moth		131.8	174	43
Hail		108.3	117	29
Total		37.3	14	3
1959				
Undamaged		61.2	37	9
Damaged		100.0	100.0	25
F.T. Leafroller		43.8	19	5
Plum curculio		307.5	945	236
Codling moth		280.0	784	196
Bud moth		325.0	1056	264
Total		56.7	32	8

TABLE VII (*cont'd*)

Estimation of numbers of trees to be sampled for a 10 and 20 per cent error, on the basis of n 25-cluster samples, for apples and apple damages from all sources.

Samplings	No. of samples per tree	C.V.$_x$[1]	n_t[2]	
			S.E. 10%	S.E. 20%
6th sampling	3			
1958				
Undamaged		43.4	19	5
Damaged		52.6	27	7
F.T. Leafroller		73.9	54	13
Plum curculio		687.5	4726	1181
Codling moth		136.5	186	46
Hail		106.6	113	28
Bud moth		210.0	441	110
Total		38.1	14	3
1959				
Undamaged		71.4	51	13
Damag d		103.4	107	27
F.T. Leafroller		202.0	408	102
Plum curculio		385.0	1482	370
Codling moth		251.6	633	158
Bud moth		172.0	296	74
Total		50.8	26	6
7th sampling, mid August	4			
1958				
Undamaged		47.3	22	5
Damaged		53.8	29	7
F.T. Leafroller		76.3	58	14
Plum curculio		262.2	687	172
Codling moth		125.0	156	39
Hail		90.6	82	20
Bud moth		137.7	189	47
Total		38.2	15	4
1959				
Undamaged		78.6	62	15
Damaged		83.3	69	17
F.T. Leafroller		93.7	88	22
Plum curculio		111.8	125	31
Codling moth		250.0	625	158
Bud moth		142.8	204	51
Total		67.6	46	11
8th sampling, mid September	4			
1958				
Undamaged		58.4	34	9
Damaged		52.7	28	7
F.T. Leafroller		63.7	40	10
Plum curculio		221.6	491	123
Codling moth		128.5	165	41
Hail		116.9	136	34
Bud moth		126.3	159	40
Total		43.4	19	5
1959				
Undamaged		72.2	52	13
Damaged		88.4	78	19
F.T. Leafroller		250.0	625	156
Plum curculio		250.0	625	156
Codling moth		180.0	324	81
Bud moth		142.6	203	51
Total		60.8	37	9

[1] Coefficient of variation (inter-tree), on the basis of n 25-cluster samples per tree, $\frac{100}{\bar{x}}\sqrt{\frac{S^2_a}{n}+S^2_t}$.

[2] Number of trees required for a 10 per cent standard error $\left(\frac{C.V._x}{10}\right)^2$; for a 20 per cent standard error, $\left(\frac{C.V._x}{20}\right)^2$.

TABLE VIII

Suggested sampling plan for studies of apples and apple damages from all sources, at various periods during the growing season, with a 10 or 20 per cent standard of error of the mean

Samplings	Number of clusters per tree	Number of trees	
		S.E. 10%	S.E. 20%
Early June	50	140	35
Late June	75	225	55
Early July	100	160	40
Mid July	175	165	45
Late July	100	255	65
Early August	75	575	145
Mid August	100	165	40
Mid September	100	200	50

cedure according to Hansen *et al.* (1953, Sec. 4.11) is to take a sample large enough for the most important variables and then accept whatever precision is attained for the less important ones. Applying this principle to the n_t values in Table VII and rounding upwards to the nearest multiple of five leads to the number of trees needed for a 10 and a 20 per cent standard error of the mean shown in Table VIII for samplings at various periods of the growing season. Also listed is the number of leaf clusters per tree on which they are based. For example, for samplings in early June, it is suggested that for a 10 per cent standard error of the mean, 138 trees be taken at random and that a 50-cluster representative sample from each tree be examined; for a 20 per cent standard error, 34 trees with a similar number of leaf clusters examined.

The n_t values in Table VIII indicate that the error in mean number of apples damaged by *A. argyrospilus*, 1st sampling, 1958 may be greater than 10 or 20 per cent when 29 or 7 trees are sampled, respectively, for total apples. The percentage standard error p is $C.V._{a}/\sqrt{n_t}$, which for the first example is $75.6/\sqrt{29}$ or 14, and for the second example $75.6/\sqrt{7}$ or 28. As a compromise for this sampling, the number of trees for total apples might be increased to 35 and 15, respectively; this would reduce the estimated standard error to 13 and 19 per cent respectively for data on apples damaged by *A. argyrospilus*. For all samplings, each of which coincides with a given period of the growing season, some upward or downward revision in the number of trees to be sampled might be needed. Nevertheless, the sampling plan outlined in Table VIII would be expected to provide a reasonable degree of precision for basic study estimates of crop and crop damages for McIntosh trees of the age class studied here.

In the present study it was found that the amount of sampling required for a specified percentage error decreased as total crop or crop damages from all sources increased. Similar observations were also made in related studies on insect population counts (LeRoux and Reimer 1959; Hudon and LeRoux, 1961). Considering that the sampling plan outlined in Table VIII results from very low figures for total crop and crop damages from all sources it is very likely that the number of trees to be sampled for higher values of total crop and crop damages would be lower than those recommended here.

Summary

Estimates of variation between samples of fruit, and of fruit damages by *A. argyrospilus*, *C. nenuphar*, *C. pomonella*, *S. ocellana*, and by hail, were made

from apple set to harvest for 35-year old McIntosh apple trees, Rougemont, Que., 1958 and 1959. Data revealed that for all samplings the greatest source of variation was between trees. Damages to the fruit by *S. ocellana* was an exception, showing between tree differences for only one sampling of the sixteen samplings made during the two-year period. For samplings of total fruit damages by other species, significant differences between blocks, levels, quadrants, level by quadrants were observed.

Based on the magnitude of the contributions made by the intra- and inter-tree variance components to the over-all variation for individual samplings, the optimum number of clusters per tree and the number of trees required to obtain a 10 and 20 per cent standard error estimate of the mean were calculated. Sampling estimates for total crop and for crop damages from all sources were made for eight periods of the growing season, namely, early and late June, early, mid, and late July, early, and mid August, and mid September. For these samplings the number of clusters to examine per tree for a 10 and 20 per cent standard error of the mean ranges from 50 to 100 clusters; an exception is the early August sampling for which 175 clusters must be examined. The number of trees from which these samples are to be taken range from 140 to 200 for a 10 per cent error (575 for the early August samplings), and 35 to 65 for a 20 per cent error (145 for the early August samplings). Crop and crop damages from which these estimates were made were low, nevertheless the sampling plan outlined would be expected to provide a reasonable degree of precision for basic studies of crop and crop damages for McIntosh apple trees of the age class studied here.

Acknowledgment

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The Rediscovery of an Unusual North American Phryganeid, with some Additional Records of Caddisflies from Newfoundland (Trichoptera)

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Most of the published references to Newfoundland caddisflies are derived from one early paper by Nathan Banks in 1908. Several collections received recently, however, have considerably extended knowledge of the Newfoundland caddisfly fauna. As might be expected, many of the species occurring in Newfoundland also extend across the whole of northern North America, and to some extent southward along the montane areas in both east and west. Some of these also occur throughout the holarctic area. Some of the species are, however, confined to northeastern North America. There are no species of caddisflies now known which are confined to the island of Newfoundland.

Specimens have come from four sources, and I am indebted to these persons and institutions for the opportunity of examining them. Most of the material comes from the collection of the Zoological Institute, Lund, Sweden, through the co-operation of Dr. Carl H. Lindroth. These collections were made by Dr. Lindroth and his associate, Dr. Henry Krogerus, during their studies in Newfoundland in 1949 and 1951. A collection was also received from Mr. A. M. Fleming of the Fisheries Research Board Biological Station, St. John's, Nfld., and has been deposited in the Royal Ontario Museum. Other records have resulted from examination of specimens, largely of the family Phryganeidae, from the Canadian National Collection, Ottawa, and from the Nova Scotia Museum of Science, Halifax. Appropriate initials following each record indicate where the material is deposited. Some of the specimens were taken in Labrador, that portion of the Province of Newfoundland on the North American mainland, and are so indicated. One series is from the French island of Miquelon, off the southern tip of Newfoundland. All others are from the island of Newfoundland itself, or from smaller offshore islands.

Probably the most interesting among these records is the discovery of additional specimens of the unusual phryganeid, *Fabria complicata* (Banks). This information is presented first, followed by the other records.

Phryganeidae

Fabria complicata (Banks)

> Cinq Cerf R. — 2 ♂, June 16, 1949, (ZIL).
> Port-aux-Basques — 1 ♂, July 1, 1949, (ZIL).
> Burgeo, Grandy Brook — 1 ♀, June 24, 1949, (ZIL).

In 1907, during the period when the Biological Board of Canada was operating the Georgian Bay Biological Station at Go-Home Bay in Ontario, a male caddisfly was taken by Dr. E. M. Walker near one of the small inland lakes or ponds in that area. The specimen was subsequently sent to Nathan Banks who assigned it to the family Limnephilidae, and described it in 1924 as representing a new species, *Ecclisomyia complicata*. Ten years later Milne (1934) recognized that the insect, in spite of its small size, was structurally a phryganeid rather than a limnephilid, and transferred it to a new genus *Fabria*, along with a much larger species *Neuronia inornata* Banks, the latter being designated the type of the genus. No additional specimen of *complicata* had ever been recorded until the present specimens from Newfoundland came to light in a collection received from the

Zoological Institute in Sweden.   The female in this series is here associated with this species because it closely resembles the males in all features except genitalia, and because this is the only species of the Phryganeidae in North America for which the female was not previously known.

Whether or not *complicata* should really be considered congeneric with *Fabria inornata* is open to question.   The species within most of the other phryganeid genera show recognizable concordance in genital structure of one or both sexes.   In the genital structures of *complicata* and *inornata*, however, there appears to be very little concordance between corresponding sexes.   Immature stages for neither species are yet known, however, and it seems best for the present to leave *complicata* in the genus *Fabria*, particularly in view of the significant generic characteristics known for larvae and pupae of the Phryganeidae (Wiggins, 1960 a, b).

ADULTS.   Length of fore wing in both sexes 12 mm.   Head and thorax medium brown, the area around the ocelli darker; warts with light hairs; antennae with alternating bands of light and dark brown; palpi and legs medium brown; legs with well developed black spines and brown spurs; spurs 2, 4, 4.   Fore wings with a light covering of brown hairs; the membrane with a light and diffuse pattern of varying shades of brown, with a rather light band through the central part of the wing, and a few light spots around the apex; hind wings without markings.   Venation (Fig. 3) the same in both sexes; M_{3+4} undivided in both fore and hind wings, and M_{1+2} undivided in the hind wings.

Male Genitalia (Fig. 1).   Ninth segment ring-like, somewhat narrowed dorsally, even narrower ventrally; posteromesal face of the ninth sternum extended as a sharp narrow ledge.   Clasper short in lateral view, two-segmented; basal segment extended ventrally, and bearing a finger-like lobe dorsally; terminal segment freely articulated and somewhat club-shaped.   Aedeagus a flattened sclerotized tube, with a very prominent, heavily sclerotized process extending strongly ventrad at each side; tenth segment complex, consisting of a pair of elongate flanges, the mesal surfaces closely appressed, the lateral edges rolled ventrolaterally to form a prominent shelf along each side; a pair of narrow dorsal processes, and a pair of much longer ventral processes; cerci knob-like, with surfaces roughened.

Female Genitalia (Fig. 2).   Subgenital plate terminating with three hairy lobes; the lateral pair curved and finger-like, the mesal lobe flattened and divided apically by a median notch.

Agrypnia colorata Hagen
         St. Anthony — 5 ♀, July 16, 1951, (CNC).
Transcontinental in the northern and montane areas of North America; not previously recorded from Newfoundland.
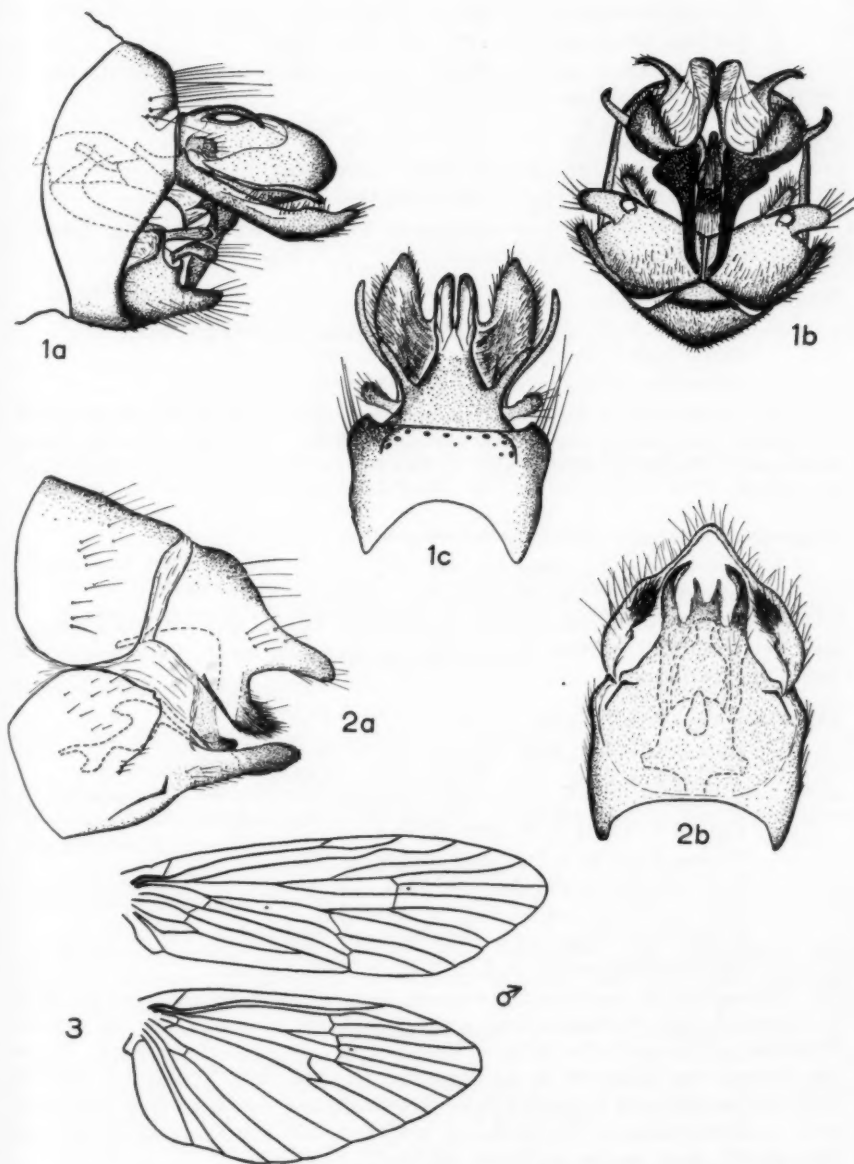
Agrypnia improba (Hagen)
         Tilting, Fogo Is. — 1 ♀, July 1, 1951, (ZIL).
Transcontinental in the northern and montane areas of North America; not previously recorded from Newfoundland.

Agrypnia straminea Hagen
         Forteau, Labrador — 1 ♀, July 13, 1951, (ZIL).
Transcontinental in the northern and montane areas of North America; not previously recorded from Labrador.

Figs. 1-3. 1, Male genitalia of *Fabria complicata*, 1a lateral view, 1b posterior view, 1c dorsal view; 2, Female genitalia of *Fabria complicata*, 2a lateral view, 2b ventral view; 3, Venation of *Fabria complicata* male.

Agrypnia macdunnoughi (Milne)

      Port-aux-Basques — 1 ♂, July 1, 1949, (ZIL).

      Forteau, Labrador — 1 ♀, July 15, 1951, (ZIL).

Transcontinental in northern North America; not previously recorded from the island of Newfoundland or from Labrador.

Phryganea cinerea Walker

      St. Anthony — 1 ♂, July 17, 1951, (CNC).

      Donovans — 1 ♀, July 27, 1954, (NSMS).

Transcontinental and very common in northern North America; not previously recorded from Newfoundland.

Banksiola crotchi Banks

      Donovans — 2 ♀, July 21, 1954; 1 ♂, Aug. 4, 1954; (NSMS).

      Cartwright, Labrador — 1 ♀, July 27, 1955, (CNC).

      Goose Bay, Labrador — 1 ♂, Aug. 14, 1949, (CNC).

The occurrence of this species in both the island of Newfoundland as well as Labrador has already been noted (Wiggins, 1956).   The record for *Banksiola concatenata* Walker given by Banks (1908) for the island almost certainly refers to *crotchi*.

Oligostomis ocelligera (Walker)

      Holyrood — 1 ♂, June 10, 1949, (ZIL).

      Grand Bruit — 1 ♂, June 14, 1949, (ZIL).

Rather local in distribution in northeastern North America, from Quebec and Newfoundland to New Jersey, west to Michigan; not previously recorded from Newfoundland.

Ptilostomis ocellifera (Walker)

      Donovans — 1 ♀, July 27, 1954, (NSMS).

      Witless Bay Line — 1 ♀, Aug. 1, 1954, (NSMS).

      St. John's — 1 ♂, July 22, 1919, (CNC).

      Gander — 1 ♂, July 4, 1949, (CNC).

      Tilting, Fogo Is. — 1 ♂, July 30, 1951, (ZIL).

      Kitty's Brook — 1 ♀, Aug. 18, 1949, (ZIL).

      Port-aux-Choix — 1 ♀, Aug. 5, 1949, (ZIL).

      Eddies Cove West — 1 ♀, July 28, 1949, (ZIL).

      Port-aux-Basques — 1 ♂, 1 ♀, June 30, 1949, (ZIL).

Throughout the northern and montane areas of North America; not previously recorded from Newfoundland under this name, although the records for *Neuronia postica* given by Banks (1908) probably apply to this species. In going through the collection of the Museum of Comparative Zoology, I failed to find any specimens of *P. postica* from Newfoundland, but there were specimens of *P. ocellifera* taken by Owen Bryant at Grand Lake and St. Anthony in 1906. Presumably, these are the specimens referred to by Banks.

Ptilostomis semifasciata (Say)

      South Branch — 1 ♀, July 3, 1949, (ZIL).

      Daniels Harbour — 1 ♀, June 22-23, 1949, (ZIL).

Throughout the northern and montane areas of North America; previously recorded from Newfoundland (Banks, 1908).
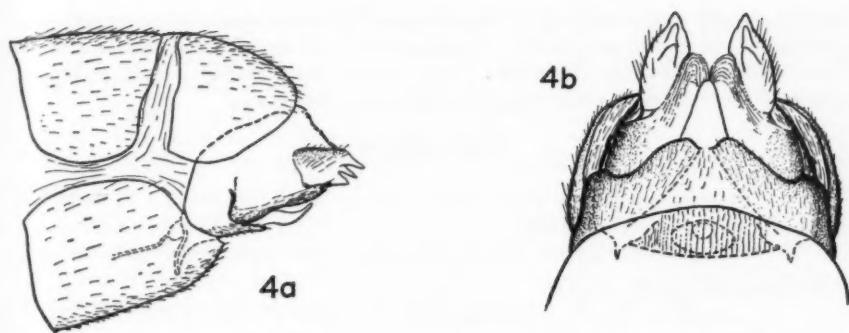
Fig. 4. Female genitalia of *Polycentropus weedi*, 4a lateral view, 4b ventral view.

Rhyacophilidae

Rhyacophila fuscula (Walker)

Grand Bank — 1 ♂, Aug. 2, 1951, (ZIL).

Widespread and common in eastern North America from Quebec to North Carolina, west to Michigan; not previously recorded from Newfoundland.

Glossosomatidae

Glossosoma nigrior Banks

L'Anse au Loup, Labrador — 1 ♂ 3 ♀, July 17, 1951, (ZIL).

Common in eastern North America; not previously recorded from Labrador.

Philopotamidae

Sortosa distincta (Walker)

St. John's — 1 ♂, June 5, 1949, (ZIL).

Grand Bank — 2 ♂, Aug. 2, 1951, (ZIL).

Forteau, Labrador — 1 ♂, July 13, 1951, (ZIL).

Widespread and common in eastern and central North America from Nova Scotia to North Carolina, west to Minnesota; not previously recorded from Newfoundland or Labrador.

Hydropsychidae

Arctopsyche ladogensis (Kolenati)

St. John's — 1 ♂, June 5, 1949, (ZIL).

Known from the Northwest Territories, Manitoba, New Hampshire, and from Scandinavia and northern parts of the U.S.S.R.; not previously recorded from Newfoundland.

Psychomyiidae

Polycentropus weedi Blickle and Morse

Flowers Cove — 2 ♂, July 25, 1949, (ZIL).

Eddies Cove West — 1 ♂, July 28, 1949, (ZIL).

Seldom, Fogo Is. — 1 ♂, July 3, 1951, (ZIL).

L'Anse au Loup, Labrador — 5 ♂ 2 ♀, July 16, 1951, (ZIL).

This species was described in 1955 from New Hampshire, and these collections from Newfoundland represent only the second series recorded. Since females were not included in the original series, figures of the female genitalia based on these two specimens from Labrador are given here (Fig. 4).

The female of this species differs from most of the other females of *Polycentropus* in that the lateral lobes of the eighth sternite are not free, but are

joined mesally with the base of an elongate triangular plate. Externally, this portion of the eighth sternite has the appearance of a broad scoop with a prominent median extension. Internally, two oblique lines extend laterad from the point of junction with the elongate triangular median plate.

Limnephilidae

Neophylax oligius Ross

St. John's (Mount Pearl Park) — 1 ♂, Sept. 7-9, 1952; 1 ♂, Sept. 16, 1953; (ROM).

Northeastern North America; not previously recorded from Newfoundland.

Glyphotaelius hostilis Hagen

Cinq Cerf R. — 1 ♀, June 16, 1949; 1 ♀, June 17, 1949; (ZIL).

Common across the whole of northern North America; not previously recorded from Newfoundland.

Platycentropus indistinctus (Walker)

Port-aux-Basques — 2 ♂, June 28, 1949, (ZIL).

Hare Bay — 1 ♂, June 21, 1949, (ZIL).

Burgeo, Grandy Brook — 1 ♂, June 24, 1949, (ZIL).

Widespread in northeastern North America; previously recorded from Newfoundland (Banks, 1908).

Pycnopsyche guttifer (Walker)

St. John's (Mount Pearl Park) — 1 ♂, Aug. 29, 1953; 3 ♀, Sept. 8, 14, 16, 1953; (ROM).

Kitty's Brook — 1 ♂, Aug. 17, 1949, (ZIL).

Widespread in northern central and eastern North America from Newfoundland to North Carolina and west to Montana and Wyoming; not previously recorded from Newfoundland.

Pycnopsyche limbata (McLachlan)

Donovans — 1 ♂, Sept. 23, 1953, (ROM).

Known from several of the provinces and states of northeastern North America, this species was originally described from specimens taken at St. John's, Newfoundland (McLachlan, 1871).

Pycnopsyche lepida (Hagen)

Glenwood — 1 ♂, August 23, 1949, (ZIL).

Widespread in northeastern North America from Newfoundland to Ontario and Michigan, to North Carolina; not previously recorded from Newfoundland.

Limnephilus ornatus Banks

Cinq Cerf R. — 1 ♂, June 17, 1949, (ZIL).

Rencontre West — 1 ♂ 2 ♀, June 17, (ZIL).

Fogo, Fogo Is. — 1 ♂, July 2, 1951, (ZIL).

Twillingate — 1 ♀, July 8, 1951, (ZIL).

St. John's — 1 ♂, June 5, 1949, (ZIL).

St. John's (Mount Pearl Park) — 1 ♀, Apr. 14, 1953; 1 ♀, July 9, 1953; (ROM).

Widespread in the northern and central parts of North America; also recorded from Greenland and Japan; previously recorded from Newfoundland (Banks, 1908).

Limnephilus sublunatus Provancher

Deer Lake — 2 ♂ 3 ♀, Aug. 18, 1949, (ZIL).

Known from northeastern North America; not previously recorded from Newfoundland.

Limnephilus hyalinus Hagen

Goobies — 6 ♂ 3 ♀, Aug. 15, 1951, (ZIL).
Deer Lake — 1 ♂, Aug. 18, 1949, (ZIL).

A northern transcontinental species; not previously recorded from Newfoundland.

Limnephilus rhombicus (L.)

Port-aux-Basques — 1 ♂, June 28, 1949, (ZIL).

Occurs throughout the holarctic region as far south as Illinois, Spain and Turkestan; previously recorded from Newfoundland (Banks, 1908).

Limnephilus nebulosus Kirby

Cinq Cerf R. — 2 ♂, June 16, 17, 1949, (ZIL).
Twillingate — 1 ♂, July 8, 1951, (ZIL).

Widespread throughout the northern part of the holarctic region; previously recorded from Newfoundland (Banks, 1908).

Limnephilus externus Hagen

St. John's (Mount Pearl Park) — 1 ♂, Sept. 7-9, 1953; 2 ♀, Sept. 16,
1953, (ROM).
Donovans — 1 ♀, Sept. 23, 1953, (ROM).

Widespread throughout the northern holarctic region, extending southward to Wyoming and Germany; not previously recorded from Newfoundland.

Limnephilus moestus Banks

Port Rexton — 6 ♀, July 30-31, 1951, (ZIL).
Gambo — 1 ♀, Aug. 26, 1949, (ZIL).
Springdale — 1 ♀, June 20, 1951, (ZIL).
Seldom, Fogo Is. — 1 ♂, July 3, 1951, (ZIL).
Tilting, Fogo Is. — 1 ♀, July 1, 1951, (ZIL).
Gaff Topsail — 1 ♀, Aug. 19, 1949, (ZIL).
Pushthrough — 1 ♂, June 22-24, 1949, (ZIL).
Rose Blanche — 1 ♂, June 27, 1949, (ZIL).
Forteau, Labrador — 1 ♀, July 15, 1951, (ZIL).

Widespread through the northern and montane areas of North America, also in Greenland; originally described from Newfoundland (Banks, 1908).

Limnephilus ademus Ross

Goobies — 1 ♀, Aug. 15, 1951, (ZIL).
Gambo — 2 ♂ 2 ♀, Aug. 26, 1949, (ZIL).
Lewisporte — 1 ♂ 1 ♀, June 26-27, 1951, (ZIL).
Badger — 1 ♀, June 22-25, 1951, (ZIL).
Pinware R., Labrador — 1 ♂, July 19, 1951, (ZIL).

Previously known only from New Brunswick. In the genitalia of these male specimens the lateral arms of the aedeagus are not quite as sharply curved dorsad as in the figure given by Ross (1941).

Limnephilus kennicotti Banks

Tilting, Fogo Is. — 4 ♀, July 1, 1951, (ZIL).
Twillingate — 1 ♀, July 8, 1951, (ZIL).
Port Rexton — 1 ♂, July 31, 1951, (ZIL).

Widespread across the northern part of North America and Greenland; not previously recorded from Newfoundland.

Limnephilus submonilifer Walker

       St. John's (Mount Pearl Park) — 17 ♂ 14 ♀, Aug. 17-Sept. 17, 1953, (ROM).

       St. John's (Fisheries Research Station) — 1 ♀, Sept. 3, 1953, (ROM).

       Holyrood — 1 ♀, June 10, 1949, (ZIL).

       Gambo — 2 ♀, Aug. 25, 1949, (ZIL).

       Terrenceville — 1 ♂ 1 ♀, Aug. 13-14, 1951, (ZIL).

       Grand Bank — 1 ♂, Aug. 1, 1951, (ZIL).

       Bonavista — 2 ♂ 3 ♀, June 19, 1953, (ROM).

       Gander — 1 ♀, June 2, 1949, (ZIL).

       Tilting, Fogo Is. — 2 ♂ 3 ♀, June 29-July 1, 1951, (ZIL).

       Miquelon Island (French) — 3 ♀, Aug. 8-10, 1951, (ZIL).

Very common throughout northern, eastern, and central North America; previously recorded from Newfoundland (Banks, 1908). The occurrence of this species on the French island of Miquelon off the south coast of Newfoundland is quite in keeping with its known habits. Adults of *L. submonilifer* often range considerable distances from their larval habitat, and are able to successfully colonize small and temporary pools.

Lepidostomatidae

Lepidostoma swannanoa Ross

       Burgeo, Grandy Brook — 4 ♂ 2 ♀, June 22, 1949, (ZIL).

Northeastern North America; not previously recorded from Newfoundland.

Lepidostoma vernalis (Banks)

       Port-aux-Basques — 1 ♂ 1 ♀, June 28, 1949, (ZIL).

Northeastern North America; not previously recorded from Newfoundland.

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Biology of Cereal and Grass Aphids in Wisconsin (Homoptera)

By G. B. Orlob[1] and J. T. Medler[2]

Research was conducted on the biology of cereal and grass aphids in the Madison area during 1957-59 in connection with epidemiological investigations of the barley yellow dwarf virus (BYDV). It becomes of increasing importance to know more about these aphids as potential vectors of the virus. Information was needed on the taxonomy, biology and ecology of the vector population to better understand the complex interactions between vector and virus. Two methods were used to obtain data on the occurrence and abundance of aphids. The conventional method of studying aphid populations on host plants was supplemented with intensive research on air-borne aphids, using the yellow-pan water trap developed by Moericke (1951), and the wind trap described by Shands (1942). These traps are shown in Fig. 1. The species of aphids were identified according to keys of Palmer (1952). Names of genera as used in Europe have been indicated in parentheses. In the following report the various forms in the life cycle are referred to as fundatrices (on the winter host), fundatrigenae (produced by fundatrices, the alates of this generation migrate to summer hosts), virginoparae (both apterous and alate individuals on summer hosts), and gynoparae (alates migrate from summer hosts to winter hosts).

Species of Aphids Occurring on Cereals and Grasses

Rhopalosiphum fitchii–padi complex–The apple grain aphid-bird cherry aphid complex–(Vector of BYDV).

This aphid was commonly found on the grain crop and certain grasses (Table I), although it was never the most abundant species in any one of the observational periods. The close similarities between *R. fitchii* (Sanderson) and *R. padi* (Linnaeus) makes it very difficult to separate the two species as virginoporae on the summer hosts. Most surveys of winter hosts in the Madison area were limited to the winter hosts of *R. fitchii* where large populations occurred. This, however does not exclude the possibility of *R. padi* being present on the summer hosts. All specimens were identified by Miss Russell as *R. fitchii*.

Fundatrices of *R. fitchii* hatched during early April before buds of the winter hosts (*Malus* sp., *Crataegus* sp.) were open. A short time later alate virginoparae appeared on grasses (*Apropyron* sp.) and winter wheat, (*Triticum aestivum* L.), presumably being dispersed by wind from areas farther south. On the winter hosts a first generation developed about three weeks after hatching of the fundatrices. This generation consisted of alate aphids which left the winter hosts during the middle of May to migrate to the grain crop. The preferred feeding site on the grain was the lower part of the stem. After maturing of small grains, small and scattered colonies were found on grasses. Migration to the winter hosts began during late September, the alate males arriving later than the gynoparae. Mating was observed in late September and during October. The eggs were predominantly deposited in the crevices of the outer part of small branches.

Apple grain aphids generally did not colonize grasses in the greenhouse. However, after confinement in cages some colonies developed upon cereal hosts. Under these conditions even gynoparae, males, and oviparae adapted themselves to cereal hosts, but fundatrices failed to do so. Under certain conditions aphids fed on roots of barley and oats.

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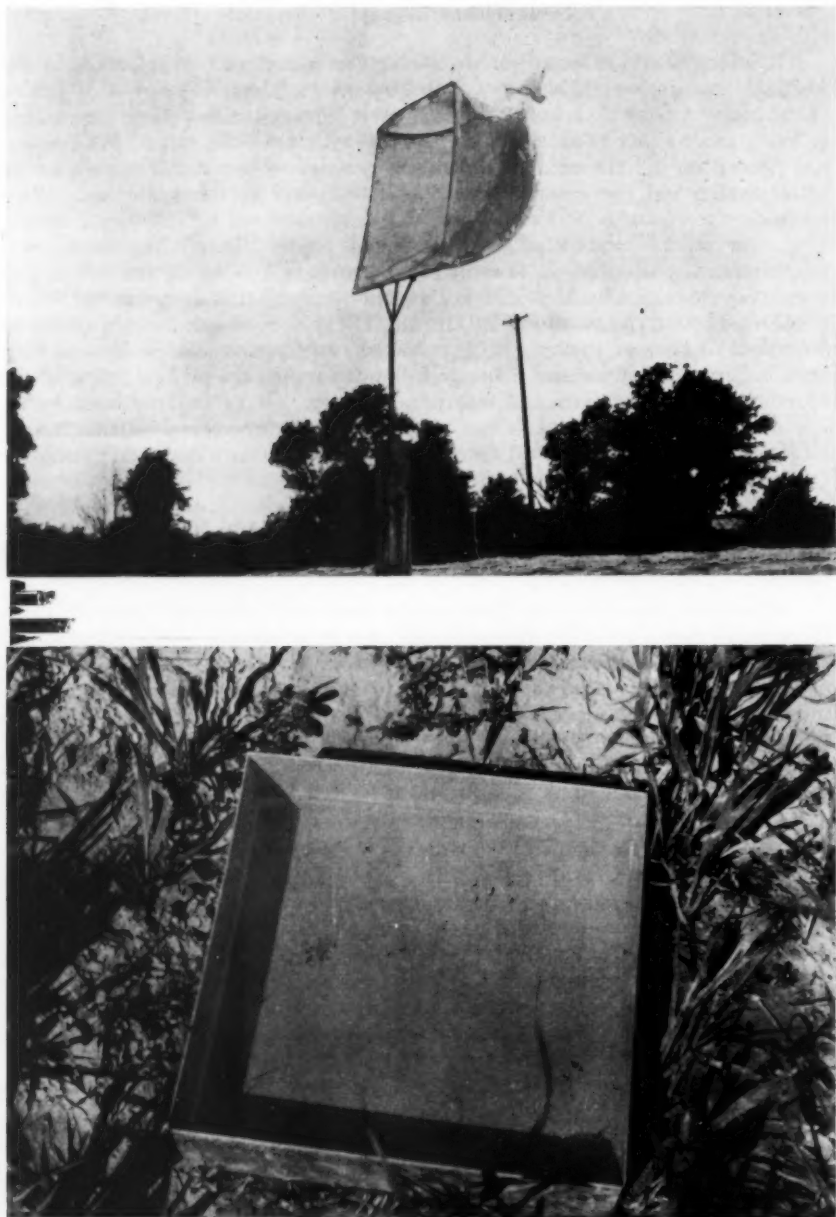
Fig. 1. Wind and yellow pan traps used in migration studies.

TABLE I

Host plant list of aphids found on grasses and cereals in Wisconsin.
a = large colonies; b = small colonies; c = individual aphid.

Host plant	Aphid species	Macrosiphum granarium (Kirby)	Macrosiphum dirhodum (Walker)	Macrosiphum pisi (Kaltenbach)	Rhopalosiphum fitchii (Sanderson)	Rhopalosiphum maidis (Fitch)	Rhopalosiphum poae (Gillette)	Sipha agropyrella Lambers	Toxoptera graminum (Rondani)	Myzus persicae (Sulzer)	Hysteroneura setariae (Thomas)	Aphis fabae Scopoli	Hyalopterus pruni (Geoff.)
Avena sativa L.		a	b	c	a	b			a	c			
Agropyron repens (L.) Beauv.		b			c	b		b	a				
Bromus inermis Leyss.		b				c						c	
Echinochloa crusgalli (L.) Beauv.					a								
Hordeum vulgare L.		a	b		a	a		c	a				
Panicum capillare L.		c				b					a		
Phalaris arundinaceae L.			b		c	c							
Phleum pratensis L.		b			c	c							
Poa pratensis L.		c			c		b						
Phragmites sp.													a
Secale cereale L.		b											
Setaria sp.		b			c	b			c			c	c
Triticum aestivum L.		b			b	b		c					
Zea mays L.		c				a							

Rhopalosiphum maidis (Fitch)—The Corn Leaf Aphid—(Vector of BYDV).

No winter forms were found. Alate virginoparae appeared on cereals at approximately the same time in the spring as did early migrants of *R. fitchii*. That these migrants can initiate early build up of colonies was shown by the fact that on May 15, 1958, several colonies consisting of one or two mature apterous females and several nymphs were found in an early planted barley plot.

In early summer the species was found on barley and sometimes was abundant locally. As it colonized corn during the summer, *R. maidis* was very common in the area, but populations dropped rapidly after maturing of corn. A wide host range was found among grasses (Table I).

The preferred feeding site of *R. maidis* on the host plant is the leaf whorl which apparently offers the species a definite protection against predators and parasites as well as adverse weather. In the greenhouse, the species developed best on barley; young corn plants were not colonized, although older plants were.

Rhopalosiphum (=*Rhopalomyzus*) *poae* (Gillette)—The Bluegrass Aphid—(Vector of BYDV).

This aphid was not found during spring or summer but was fairly common during the fall on *Poa pratensis* L. Thus, although the species is an efficient vector it does not contribute to primary or secondary spread of BYDV in summer grain in Wisconsin. The aphid was difficult to find on bluegrass because it feeds on the lowest part of the stem. In the greenhouse, the species adjusted well to barley and oats, producing large colonies. Whether *R. poae* migrated between *Lonicera* sp.

and *Poa* sp. or whether it hibernated holocyclicly on bluegrass could not be determined.

Macrosiphum granarium (Kirby)=(*Sitobium avenae* (Fabricius))—The English Grain Aphid—(Vector of BYDV).

Alate virginoparae appeared during April simultaneously with *R. fitchii*. This species was the most uniformly abundant aphid on small grains in the spring and early summer, except during an outbreak of *Toxoptera graminum* (Rondani) in 1959. Large populations were locally abundant on winter grain during late September and October. Extensive searches during fall and spring gave no indications of holo- or anholocyclic overwintering. It is probable that *M. granarium* is established in Wisconsin each year by migrants blown in from the south.

English grain aphids were found on the upper part of oat plants, and migrated to the heads where they fed on the spikelets as the crop matured.

Several grasses were fed upon, but colonies on these hosts remained small (Table I). This was also true when aphids were placed on grass species under greenhouse conditions.

After transfer to test plants *M. granarium* appeared to probe more readily than did other species. It also punctured different membranes, and several aphids were observed attempting to probe into the dorsum of other aphids.

Since the English grain aphid was the most abundant species on oats, some observations were made on its predators and parasites. Coccinellids and syrphid larvae were the most important predators. In certain localities, parasitism by ichneumonids was common. Very few specimens were found infected with fungi.

Macrosiphum (=*Metopolophium*) *dirhodum* (Walker)—The Rose Grass Aphid—(Vector of BYDV).

This species produced large colonies on *Phalaris* sp. during the midsummer of 1957. It appeared that colonies were most numerous on young succulent plants growing under moist conditions. It was found on oats very rarely and not before the end of June. No forms were found on *Rosa* sp., the winter host. The species was well adapted to the greenhouse and produced large colonies on barley which were used for mass infection with BYDV. It seemed, however, that barley was susceptible to damage by this species, and plants soon died when heavily infested. An observation on the production of eggs in these cultures was published by Orlob and Medler (1960).

Toxoptera (=*Schizaphis*) *graminum* (Rondani)—The Greenbug—(Vector of BYDV).

Only a few specimens were found in 1957 and 1958, but large numbers appeared on oats during the spring and summer of 1959. The outbreak was associated with a long-distance dispersal by wind of alates from areas south of Wisconsin. Individual greenbugs caused reddish-brown feeding spots on oats, and colonization was followed by leaf discoloration and a general decline of the infested plants. Heavy feeding by the greenbug produced injury that could be confused with symptoms of barley yellow dwarf virus disease. In nature, the greenbug was rarely found on grasses (Table I); but in the greenhouse it developed well on several species of grass. No evidence for anholocyclic or holocyclic overwintering was obtained. Outbreaks of the greenbug in northern states were discussed by Wadley (1931) and Medler and Smith (1960).

Sipha agropyrella Lambers—The Quackgrass Aphid.

The winter was passed as eggs on *Agropyron repens* (L.). Fundatrices hatched during the latter part of April. This aphid was commonly found on

Agropyron and sometimes occurred abundantly enough to damage its host. Necrotic patches developed around feeding sites and became enlarged until the entire leaf was killed. In the field the quackgrass aphid was monophagous on *Apropyron*, except that an occasional migrant was found on wheat and barley. Aphids confined to barley in the greenhouse developed colonies of considerable size. This species did not transmit BYDV.

Hysteroneura setariae (Thomas)—The Rusty Plum Aphid.

This aphid was never observed before August, but at that time regularly colonized *Panicum capillare* L. No search was made for overwintering forms on the winter host. Apparently aphids leave the winter host late in the season. The species adapted itself to barley under greenhouse conditions, but did not transmit BYDV.

Hyalopterus pruni (Geoff.)—The Mealy Plum Aphid.

The species alternated between plum as the winter host and *Phragmites* sp. as the summer host. It was found on both hosts; on the winter host even during summer. Individual migrants also were collected from *Echinochloa crusgalli* (L.). In limited trials, adaptation to barley in the greenhouse was not successful.

Pamphigini and Fordini—Root Aphids

Several species in these tribes were found on roots of grasses. The local abundance of the aphids in certain areas was associated with favorable ecological conditions at collection sites. Root aphids had a negative role in transmission experiments with BYDV.

Observations on Non-cereal Aphids

A few migrants of *Myzus persicae* (Sulzer) were collected on oats, but the species did not colonize on this host in the field. Barley and oats were sometimes extensively colonized in the greenhouse, but the species was unable to transmit BYDV. Migrants of *Aphis fabae* Scopoli were found on oats, *Setaria* sp. and *Bromus* sp. Migrants of *Macrosiphum pisi* (Kaltenbach) and *Macrosiphum solanifolii* (Ashmead) were observed on oats. All of these species were considered as "chance" visitors on grain; landing and taking off after limited feeding attempts.

Host Plant Preferences

The collections on various host plants are summarized in Table I. According to their host plant preference, the cereal and grass aphids can be divided into three groups. This division is based upon field observations and is not sharply defined. Also, as mentioned previously, some specie may adapt themselves to host plants in the greenhouse but not colonize the same plants in the field.

Group 1. Cereal aphids. In this group belong *M. granarium*, *R. fitchii* and *T. graminum*. These aphids had small grains as their primary food plant. They did not colonize grasses in large numbers. During early April some migrants of *R. fitchii* and *M. granarium* were found on quackgrass, but not more than a few nymphs were deposited and colonies remained small. After maturing of the small grains, these species were perpetuated on several grasses, including *Setaria* sp. which is preferred by *M. granarium*. Generally, all species of this group did not develop well on grasses in the greenhouse.

Group 2. Cereal and grass aphids. *R. maidis* and *M. dirhodum* had a less pronounced preference for cereals and developed equally well on certain grasses, such as *M. dirhodum* on *Phalaris* sp. However, *R. maidis* developed its largest populations on barley and corn.

  Group 3. Grass aphids. All species placed in this group were more or less monophagous on their respective grass hosts and did not colonize cereal in the field. *R. poae, H. setariae, H. pruni* and *S. agropyrella* are typical of this group. However, all of these aphids except *H. pruni* adapted themselves to barley under confinement in the greenhouse.

Some Relations Between Host Plant Preferences and BYDV

  Aphids began to colonize summer hosts, including cultivated cereals, with the arrival of migrants from the south or from winter host plants. Winged migrants had a restless feeding behavior and were able to introduce and spread BYDV, although the percentage of aphids which were viruliferous was usually small. Normally the vector pool of BYDV was composed of *M. granarium, R. fitchii,* and *R. maidis.* The three species were present in the same relative proportions in each of the three years, 1957-59, with *M. granarium* being most common in spring and fall, and *R. maidis* most prevalent in the summer. In addition, *T. graminum* appeared in larger numbers in the spring of 1959.

  The present study showed that several species colonized grain and grasses at different times of the growing season and because of this some of them could play only a minor role in virus transmission. Acceptance of a plant by a vector depended, apparently, both on the taxonomic and physiological status of the plant (Kennedy *et al.* 1959). For example, quackgrass was colonized by *M. granarium* when the plant was young, but not during later stages of growth. Host range studies in the greenhouse may be misleading, as under confinement several species adapted themselves to hosts that were not colonized in nature, or colonized only during certain growth stages of the host. The grass aphids contributed only a small fraction of the total aphid populations. Species such as *M. granarium, R. maidis* and *T. graminum,* which spend at least a part of their life cycle on cereals and do not overwinter in the Madison area, were usually most prevalent. Their life cycles were synchronized with the early growing stages of the cereals. Thus, cereals are physiologically and ecological superior to grasses in attracting and colonizing vectors. Since very few aphids were found on grass hosts of BYDV during spring and early summer the role of grasses in the epidemiology of the disease was difficult to assess.

Results of Trapping Air-borne Aphids

  Each year several color and wind traps were placed in an early planted oat field at the University Farms. The numbers of air-borne aphids trapped during 1957-59 are given in Fig. 2. The two types of traps supplied different kinds of information. The yellow pans measured aphid behavior as a direct response to color, whereas the wind trap merely sampled aphids in the air regardless of behavior. The color traps had highest counts during calm weather, and the wind traps during windy days. Both cereal and non-cereal aphids were caught. However, the color traps were less attractive to certain cereal aphids than they were to species that feed on dicotyledonous plants. Usually the number of non-cereal aphids was considerably higher than the number of cereal aphids. At times, however, the cereal aphids predominated, such as during April when they were the only species caught. During May the variety of aphid species increased and non-cereal aphids became more numerous. Summer migrations of cereal aphids were not noticeable, other than in mid-summer when *R. maidis* was common. Summer migrants from corn contributed largely to this population in the air (up to 85 per cent). Later in the fall, the greater catches of cereal aphids indicated migrations, especially of *M. granarium* and *R. fitchii.* For best results it is believed that trapping should be complemented by field observations, as some migrations
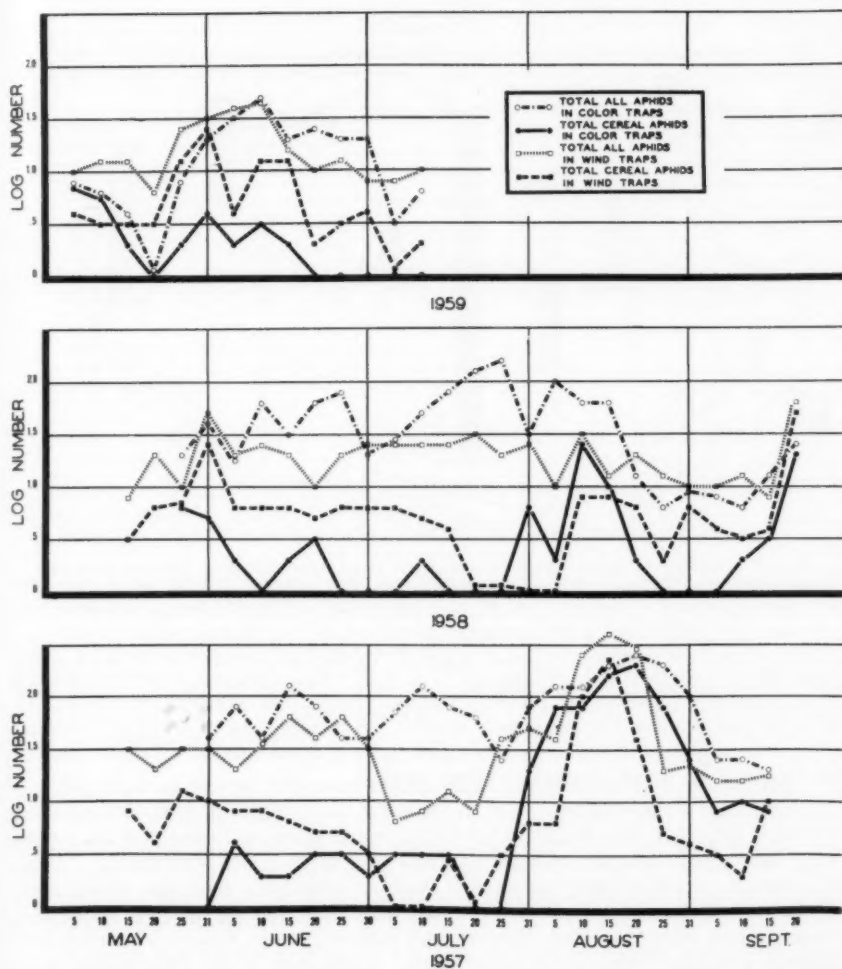
Fig. 2. Number of aphids caught in 4 color and 2 wind traps in oat fields at Madison, Wisconsin, 1957-1959.

may be too weak to be registered by traps. Field studies have the additional benefit of associating the aphid with its host plant.

The species in the traps varied according to the placement of traps. Although the air-borne populations seemed to be well distributed over a given area, the relative abundance from one trap to another was influenced by vegetation and topography. Differences between traps placed in close proximity to each other were caused by the condition of a field, the prevailing wind direction and the location of traps in the interior or at the margin of a field.

Traps located at the edges of an oat field yielded higher counts than those either in a central position or placed at the margin that was closely bordered by another crop (Fig. 3). Border infestations apparently were caused by more widely spaced plants and the presence of an area of bare soil along the margin of
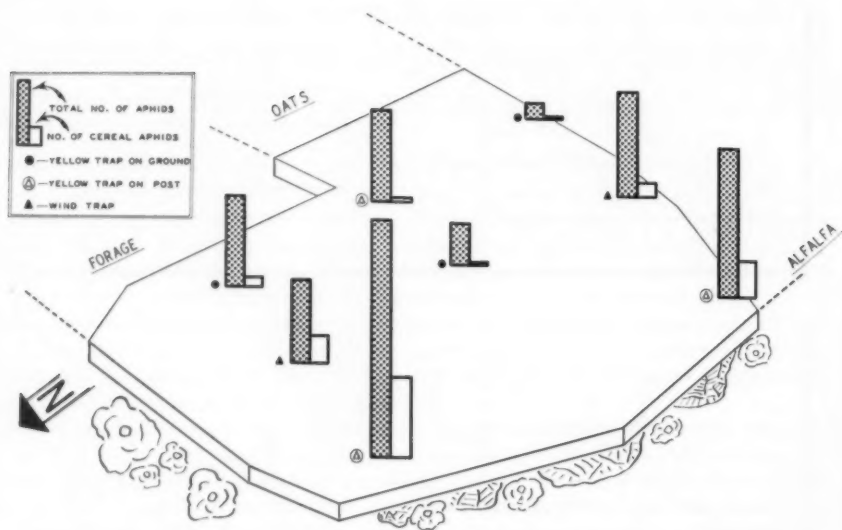
Fig. 3. Number of aphids caught in color and wind traps placed at different locations in an oat field, 1957.

a crop which "absorbed" aphids and allowed relatively few individuals to penetrate deeper into the field (Müller, 1957). It was therefore not surprising to find in most cases a gradient of BYDV infected plants with the highest number of infected plants along the margins of a field. Accumulation of aphids on certain areas also might be favored by air drifts which cause aphids to alight on the leeward side of woods, hedges or other barriers.

The traps were of great value in studying life cycles. It was noted during 1958 and 1959 that alate *R. fitchii* colonized winter grain and grasses in the spring when fundatrices had just hatched on the winter hosts under observation. Thus, alate aphids on the summer hosts could not have originated from the winter host. These individuals either had overwintered anholocyclicly in Madison or nearby areas, or had been dispersed from regions where a more favorable climate had allowed an earlier build-up of populations. Each year at the time aphids were first trapped the wind directions seemed favorable for long distance dispersal. Low pressure centres located over southwestern Kansas resulted in winds rotating over northern Texas, Oklahoma, Arkansas, and southern Missouri into Wisconsin.

The possibility of anholocyclic overwintering was tested during the three-year period. In the fall specimens of *R. fitchii*, *R. maidis* and *M. granarium* were exposed in various locations and survival checked in the fall, winter and spring. Aphids were killed by the first severe frosts and no overwintering could be demonstrated.

To test the hypothesis of long distance wind dispersal, yellow pan traps were operated in Missouri and Kansas as well as Wisconsin in 1959. The trapping records indicated unusual activity of alate cereal aphids, especially *T. graminum*, in Missouri and Kansas during the last week of April. The sudden appearance of migrants at Madison during May 3 to 6 was associated with an extensive warm front covering much of the eastern half of the United States. Within this weather system strong southerly winds prevailed at 20 to 30 miles per hour. A 20 miles

TABLE II

Length of time spent by alate *M. granarium* on oat plants during spring migrations — 1958.

Date experiment started	No. of marked aphids	No. of aphids which left plants after (hours)					
		0-5	5-10	10-20	20-30	30-40	>40
5/24	15	5	0ª	9	0	0	1
5/24	15	3	0	8	0	0	4
5/25	10	4	0	3	0	0	3
5/25	10	6	0	4	0	0	0
5/26	10	5	0	1	0	0	4
5/28	11	4	0	0	4	3	_ᵇ
6/2	15	4	0	2	1	–	8
6/4	10	–	3	0	5	2	–
6/6	10	–	–	–	3	2	5
6/9	11	3	0	–	7	1	–
6/10	11	6	0	0	5	–	–
6/11	10	–	2	0	–	3	5
% leaving plants		29	4	19	18	8	22

[a] No change, colonization as in previous period.
[b] No observation made; if aphids left, numbers are included in the following period.

per hour wind on the surface (above surface winds are stronger) would enable aphids to be dispersed possibly 480 miles in a 24 hour period. The hypothesis of widespread dispersion of aphids for long distances from south to north may be difficult to prove, but circumstantial evidence strongly suggests that such phenomena occur. That the migrants were also carrying virus is suggested by the fact that symptoms of BYDV appeared in oat fields 17 days after the first infestation by *T. graminum* was noticed.

Behavior of Spring Migrants During the Colonization of Grain Fields

Testing aphids on their ability to transmit a virus means little if these findings are not followed by studies on how aphids find, select, and colonize a host. In the present research, some aspects of the flight behavior of *M. granarium* were studied from May 24 to June 11, 1958, after similar trials had been performed during the same period of 1957.

In an oat field the feeding position of each alate virginoparae found on a plant was recorded by a marking system and checked at various intervals (Table II). When aphids were not found in the same position or on sites reached by walking, they were considered to have left the plant. Infestation of a plant by two aphids or reinfestation after the recorded aphid left were rare under the condition of the experiment. Marking was started when the spring migration had reached a peak, and was conducted both in the morning and in the early afternoon. It was found that 29 per cent left the plant during 0-5 hr., 24 per cent during 5-20 hr., 26 per cent during 20-40 hr., while the rest remained more than 40 hr. on the plant. Most of the aphids of the last group probably were unable to leave again. Larviposition occurred predominantly in the groups which stayed on the plants longer than 5 hr.

"Dispersive" migrants are included within the first interval (0-5 hr.). With increasing time the experiment tended to become less accurate, and it cannot be stated with confidence that all aphids left after the first time periods indicated. Results were difficult to evaluate because the actual time spent by aphids on the

host was not determined. Nevertheless it appeared that a certain proportion of aphids remained on the host for several hours before they left. These "sedentary" migrants may acquire BYDV after alighting on an infected plant. According to studies in the greenhouse at least seven to nine hours of feeding were needed for aphids to become viruliferous.

Additional evidence on the restless behavior of spring migrants was obtained by searching on oat leaves for the necrotic spots which characterized the feeding of *T. graminum*. Such feeding spots were found abundantly following the green-bug infestation on May 2 to May 6, 1959. However, relatively few migrants were found on plants "marked" with feeding spots and only occasional nymphs were present. These observations indicated that early spring migrants visited many plants before they became sedentary.

In other experiments during 1957 and 1958, it was shown that aphids were able to find preferred host plants within a non-host vegetation. Single oat and barley plants were placed in a field of cabbage, a pea field, along the margin of woods, and in a densely weeded area. Most plants became infested by grain aphids, principally *R. maidis*. Such experiments did not indicate how the aphids found their host, but circumstantial evidence suggested that this was accomplished by chance alighting rather than by active attraction to the host. Test plants were mostly colonized by the aphid species which was most abundant in the area. On the other hand, the same species (*R. maidis*) alighted in considerable numbers on tobacco, a non-host; whereas non-cereal aphids also alighted on oats.

A phenomenon referred to by Moericke (1955) as swarming or dancing was sometimes observed during warm fall days. In one instance (Madison, Oct. 16, 1957) several aphid species (*Aphis helichrysi* (Kaltenbach), *Aphis pomi* (De Geer), *Myzus persicae* (Sulzer)) as well as those of the *R. fitchii-padi* complex were found to alight on peach trees. With the exception of *M. persicae*, peach is a non-host of these aphids. All aphids, however, after a period of walking or probing took off again and a considerable number of them accumulated on the leeward side of the trees. It seemed that this swarm was made up of aphids constantly alternating between alighting and taking off. No nymphs of any species were found on the trees at that time.

Key to the Species of Aphids Likely to Occur on Cereals and Grasses in Wisconsin

The following key has been prepared for the convenience of workers who are interested in identifying the more common and economically important species of cereal and grass aphids. As the key is designed for practical purposes, it is based on simple recognition characters which can be seen with the aid of a hand lens. It should be expected that an occasional polyphagous species may be collected in grain that cannot be identified with the key.

1. Aphids on roots . . . . usually Pemphigini and Fordini
   Aphids on leaves or stems 2
2. Body with numerous long, sharp, spine-like hairs; cornicles ringlike, inconspicuous;
   fairly common on quackgrass (quackgrass aphid) . . *Sipha agropyrella* Lambers
   Body without spine-like hairs; cornicles cylindrical, conspicuous, at least as long as
   hind tarsi 3
3. Aphid light colored; green or yellowish 4
   Aphid dark colored; brown, red or black 8
4. Body surface powdery, on *Phragmites communis* (mealy plum aphid). . . . . .
                                                   Hyalopterus pruni (Geoff).
   Body surface not powdery, host otherwise 5

5. Body shape round; all appendages pale, size: 1.8-2.0 mm.; cornicles slightly swollen in summer and fall forms. Abdomen with dark blotches in winged forms. Observed rarely on small grains, on other hosts fairly common (Green peach aphid) . . *Myzus persicae* (Sulzer)

     Body shape elongate 6

6. Aphid grass green; cornicle entirely black; legs pale with dark tips. Common on small grains, (English grain aphid) . . . . *Macrosiphum granarium* (Kirby)

     Aphid yellow or green; without entirely black cornicle 7

7. Aphid yellowish; antennae pale. Size 2.4-2.8 mm. In winged form, the media twice branched. On *Phalaris* sp., rare on small grains (Rose grass aphid) . . . . *Macrosiphum dirhodum* (Walker)

     Aphid green, antennae dusky. Size 1.2-2.0 mm. In winged form, the media not branched. Usually rare, but in some years very common on grain leaving necrotic feeding spots (Greenbug) . . . . *Toxoptera graminum* (Rondani)

8. Body shape elongate; bluish-green to violet; hind tibiae unicolorous. Very common in summer feeding in leaf whorl of grain, corn, grasses (Corn leaf aphid) . . *Rhopalosiphum maidis* (Fitch)

     Body shape round 9

9. Aphid reddish to brown; tibiae white. Appearing in late summer on *Panicum* sp. (Rusty plum aphid) . . . . *Hysteroneura setariae* (Thomas)

     Not as above 10

10. Aphid brownish, with orange to dark spot around base of cornicle. Common on small grains (Apple grain aphid) . . . . . . *Rhopalosiphum fitchii-padi* complex

     Aphid dark brown or black, shining; antennae long and curved, legs dusky. Fairly common on blue grass in the fall (Bluegrass aphid) . *Rhopalosiphum poae* (Gillette)

Summary

1. Some aspects of the biology of aphids found on cereals and grasses were studied. According to host plant preferences, the species in the Madison area were divided into three groups: (1), cereal aphids, (2), grass and cereal aphids, and (3), grass aphids.

2. The early populations of the *Rhopalosiphum fitchii-padi* complex on grasses and winter grain were established by migrants originating outside of Wisconsin. *Macrosiphum granarium, Rhopalosiphum maidis*, and *Toxoptera graminum* were likewise established following wind dispersal from areas to the south.

3. Information on the abundance and behavior of cereal aphids on host plants and in the air served as a basis for epidemiological studies on BYDV. Along with the high numbers in populations of the vector species, spread of virus in the field was facilitated by the restless feeding behavior of alate migrants. Wind traps and yellow-pan water traps were used to obtain data on the abundance and activity of the alate populations. During the three-year period, the major vector pool of BYDV was composed of *M. granarium, R. fitchii*, and *R. maidis*. In addition *T. graminum* was present during an outbreak in 1959.

4. A simple recognition key is provided for the identification of the cereal and grass aphids in the Madison area.

Acknowledgments

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Notes on Parasites of the Wheat Stem Sawfly, *Cephus pygmaeus* (L.) (Hymenoptera: Cephidae) from Continental Europe

By R. W. Smith

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Larvae of the European wheat stem sawfly, *Cephus pygmaeus* (L.), in hibernacula in wheat stubs were obtained from Russia and Sweden in the fall of 1959 by the Entomology Research Institute for Biological Control in a renewed attempt to find parasites for use against the wheat stem sawfly, *Cephus cinctus* Nort., in Western Canada. An earlier attempt to colonize the parasite *Collyria calcitrator* (Grav.) from England failed in spite of early promise of success (Smith, unpublished reports). Though *Collyria* spp. were expected to predominate in the Continental collections, their different geographical origins opened the prospect of finding different species or strains better suited to Canadian conditions. There was also the possibility of discovering additional parasites suitable for trials in Canada.

All collections reached the Institute at Belleville in October or November and were held in cool storage (8°C.) until placed in incubation for emergence of parasites the following summer. The Russian collections were sent by way of the Commonwealth Institute of Biological Control, Delemont, Switzerland, and the Swedish collections direct from Lund.

The source localities and the estimated number of wheat stubs with sawfly larvae were as follows:

Ukraine		Caucasus		Sweden	
Chernovsky	3200	Krasnodar	1000	Lund	980
Kirovograd	1000	Stavropol	460	Strovelstorp	200

The parasites obtained from these collections were as follows:

	Collyria calcitrator	Scambus detritus	Bracon terebella	Norbanus scabriculus	Eupelmus atropurpureus
Chernovsky	530	—	—	1	1
Kirovograd	162	—	3	—	4
Krasnodar	63	—	—	—	—
Stavropol	5	—	—	1	—
Lund	380	—	20	—	—
Strovelstorp	26	1	2	—	—

All the species listed above are primary parasites of *C. pygmaeus* and all but *Collyria* are ectophagous.

Almost 50 per cent of the sawfly larvae were still in diapause in mid-August, when emergence had ceased. These were retained for further study. The sawflies constituted scarcely seven per cent of the emergents.

Scambus detritus (Holmg.) has already been reported as a parasite of *C. cinctus* in Western Canada (Holmes, 1953), and was reared from *C. pygmaeus* in Ontario, in 1953 (Smith, unpublished record). Salt (1931, p. 519) experienced some difficulty in determining the species of *Scambus* (*Pimpla*) found in *C. pygmaeus* in England, but concluded that it was *S. detritus*. Further to this, it may be noted that the dentate labial ring of a larval cast associated with a female from Strovelstorp had, in addition to a median tooth, six marginal teeth rather than four as shown by Salt for the English specimens.

Bracon terebella Wesm. is a species also associated with *C. pygmaeus* in England, but because it was not abundant there and because *Bracon cephi* (Gahan) was already the most important parasite of *C. cinctus* in Western Canada, Salt (1931) did not favour its introduction. The species was reared from *C. pygmaeus* in Ontario (Smith, 1948). One to several individuals may develop on a single host.

All *Collyria* adults were identified as *C. calcitrator* (Grav.). There was some variation in the immature larvae in the number and arrangement of sensoria on the lower anterior area of the second stage head capsule. They also varied in this respect from Salt's (1931) description of specimens from England. However, the bilateral asymmetry often associated with these characters suggests that they are not of specific importance. *Collyria* emerges in the spring or early summer and lays its eggs in sawfly eggs lying within the hollow wheat stems. It emerges three or four days before its usual host, *C. pygmaeus*, and both are ready to lay eggs within a day of emergence. The interval between the emergence of *Collyria* and *C. pygmaeus* in the laboratory was the same in collections from all localities. Under the same conditions, adults of *C. cinctus* emerged two to four days after those of *C. pygmaeus*, so that development of the parasite would seem to synchronize sufficiently well with that of *C. cinctus*. In the laboratory the parasites located eggs of *C. cinctus* as readily as those of *C. pygmaeus*, but laboratory propagation was not sufficiently successful to show whether the Continental strains could develop in the nearctic *C. cinctus*. However, in the laboratory their propagation was no more successful in *C. pygmaeus*. On the limited evidence available there is nothing to suggest that they would be either more or less successful in Western Canada than the English strain. The English *Collyria* completed two annual generations in *C. cinctus* at Swift Current, Saskatchewan, from 1931 to 1933, surviving the two intervening winters successfully. The species also passed the winter of 1933-34, in the same area with negligible mortality (Smith, unpublished reports). Nevertheless, it is not known to be established in Western Canada, though it has done well on *C. pygmaeus* in

Ontario (Smith, 1959). A few (119) *C. calcitrator* from Chernovsky were released near Lethbridge, Alberta, on June 28, 1960, but no effort has yet been made to determine their success.

Norbanus scabriculus (Nees) is a species often mentioned with *Collyria* as a parasite of wheat stem sawflies in Europe, but its scarcity in England and in the Continental collections of 1959 does not mark it as a parasite of special importance. Little is known of its life history. Professor Rubzov, who provided the collection from Stavropol, stated that it sometimes emerges in August from stubs infested the same season; and, in fact, three individuals emerged from the Stavropol collections in September while at Delemont, Switzerland. The two females obtained at Belleville, after overwintering (in storage) appeared with the latest *Collyria*. On the other hand, *Norbanus* from stubs imported from England in the 1930's, appeared at the same time as the earliest *Collyria*. It is possible that *Norbanus* has more than one generation a year, or that some overwinter as larvae, pupae, or adults within the stems. If most overwinter as adults outside the stems it would account for the scarcity of *Norbanus* from overwintered stubs.

The two females obtained at Belleville showed no interest in either sawfly-infested stems or stubs, and for the most part rested quietly on the sides or tops of the cages and rarely moved unless disturbed. They showed no interest in the various foods provided but did drink when the cages were sprayed with water. One female remained alive for 38 days at 24° C. and one for 48 days at 22°c. The relative inactivity of these two individuals adds further to the surmise that the species overwinters in the adult stage.

Two types of pupal cases were found in sawfly hibernacula after emergence was over. These presumably were of *Norbanus scabriculus* and *Eupelmus atropurpureus* Dalman. Small lots of stubs incubated individually produced neither of those species, and unfortunately no adults were linked with the pupal cases. One type of case and the larval casts associated with it have much in common with those of *Eupelmus allynii* (French), as illustrated and described by Hill and Pinckney (1940). The other type of case is slightly larger and more heavily pigmented, with the abdominal terga fused and not demarcated. It is considered to be that of *N. scabriculus*. The species represented by these pupal cases are evidently external primary parasites that attack the sawfly in its hibernaculum. Whether they also attack the sawfly higher up in the stem is not known. Some, but not all, of the sawflies killed by these ectophagous parasites contained *C. calcitrator;* under such conditions *Collyria* dies with the host.

The absence of *Pediobius beneficus* (Gahan) from the Continental collections was unexpected. This species is relatively important in England and was almost half as abundant as *Collyria* in the wheat stubs imported from England in the years 1935 and 1937, though less abundant in the other years between 1929 to 1939. It has been reared from wheat stem sawflies in the eastern United States (Udine, 1941), and parasitized 30 per cent of *C. pygmaeus* larvae collected in Ontario in 1944 (Smith, 1959). *P. (Pleurotropis) beneficus* was first described by Gahan (1921, p. 117) from *Cephus (Trachelus) tabidus* (Fab.) collected in Pennsylvania. Salt (1931) noted that his own rearing of the species was the first record of its occurrence in Europe. Gahan (1932, p. 751) later suggested that it might be going under some other name in Europe but found that it differed from *Pleurotropis nitifrons* Thoms. and *P. nigritarsis* Thoms., the species it most closely resembled. Could it be that *P. beneficus* is a nearctic species that has found its way to England?

Summary

Larvae of the European wheat stem sawfly were obtained from Russia and Sweden in 1959 in a renewed attempt to find parasites for use against the wheat stem sawfly in Western Canada. Five primary parasites were found. *Collyria calcitrator*, an internal parasite, predominated but seemingly did not differ from the strain previously imported from England. The occurrence of the external parasites *Bracon terebella*, *Norbanus scabriculus*, and *Eupelmus atropurpureus* result in casualties to *Collyria*. *Pediobius beneficus*, a parasite of some importance in the wheat stem sawflies in England, the northeastern United States, and Ontario was absent from the Continental collections.

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Nomenclature Notice

In accordance with a decision of the 13th International Congress of Zoology, 1948, public notice is hereby given of the possible use by the International Commission on Zoological Nomenclature of its plenary powers in connection with the following cases, full details of which will be found in *Bulletin of Zoological Nomenclature*, Vol. 18, Part 3 to be published on 16 June, 1961.

(1) Validation of the generic name *Cicadella* Latreille, 1817 (Insecta, Hemiptera). Z.N.(S.)457;

(2) Designation of a type-species for *Conomelus* Fieber, 1866 (Insecta, Hemiptera). Z.N.(S.)468;

(3) Suppression of the generic name *Cerastes* Laurenti, 1768 (Reptilia). Z.N.(S.)724;

(4) Suppression of the generic name *Siredon* Wagler, 1830 (Amphibia). Z.N.(S.)730;

(5) Designation of a type-species for *Aphis* Linnaeus, 1758 Linnaeus, 1758 (Insecta, Hemiptera). Z.N.(S.)881;

(6) Validation of the generic name *Anilius* Oken, 1816 (Reptilia) Z.N.(S.)1046;

(7) Validation of the generic name *Panopea* Ménard de la Groye, 1807 (Bivalvia). Z.N.(S.)1049;

(8) Designation of a type-species for *Dasiops* Rondani, 1856 (Insecta, Diptera). Z.N.(S.)1240;

(9) Designation of a type-species for *Harrisoniella* Bedford, 1928 (Insecta, Mallophaga). Z.N.(S.)1282;

(10) Designation of a type-species for *Lestis* Lepeletier & Serville, 1828 (Insecta, Hymenoptera). Z.N.(S.)1383;

(11) Suppression of the specific name *gulosus* (*Tylenchus*) Kühn, 1890 (Nematoda). Z.N.(S.)1432;

(12) Suppression of the specific name *planiceps* (*Hyracodon*) Scott & Osborn, 1887 (Mammalia). Z.N.(S.)1438;

(13) Validation of the generic name *Pnoepyga* Hodgson, 1844 (Aves). Z.N.(S.)1457;

(14) Suppression of eight turtle specific names (Reptilia). Z.N.(S.)1459;

(15) Validation of the specific name *tigrina* (*Salamandra*) Green, 1825 (Amphibia). Z.N.(S.)1460;

(16) Designation of a neotype for *Corvus benghalensis* Linnaeus, 1758 (Aves). Z.N.(S.)1465;

(17) Suppression of the specific name *dubia* (*Amphisbaena*) Rathke, 1863 (Reptilia). Z.N.(S.)1466;

(18) Suppression of the specific name *erythronota* (*Salamandra*) Rafinesque, 1818 (Amphibia). Z.N.(S.)1467;

(19) Suppression of the specific name *reticulata* (*Amphisbaena*) Holmer, 1787 (Reptilia). Z.N.(S.)1468.

Any zoologist who wishes to comment on any of the above cases should do so in writing, and in duplicate, as soon as possible, and in any case before 16 December, 1961. Each comment should bear the reference number of the case in question. Comments received early enough will be published in the *Bulletin of Zoological Nomenclature*. Those received too late for publication will, if received before 16 December, 1961, be brought to the attention of the Commission at the time of commencement of voting.

All communications on the above subject should be addressed as follows:

The Secretary,
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LONDON, S.W.7,
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W. E. CHINA,
Assistant Secretary to the
International Commission on
Zoological Nomenclature.

May, 1961.

Book Reviews

Sound Production and Sound Reception by Insects — A Bibliography, by Mable Frings and Hubert Frings. The Pennsylvania State University Press, University Park, Pa., 1960. 108 pages. Price $4.00.

This compact and attractively produced volume lists 1752 references to books and articles on sound production and sound reception. The bibliography is intended to be nearly complete for titles to the end of 1957, but it lists some as late as 1959. A spot check of several moderately obscure papers showed that every one was listed. Books have not fared quite so well: Longstaff's *A Butterfly-Hunter in Many Lands* and Hering's *Biologie der Schmetterlinge,* for instance, are not cited. In general, however, the list of references is obviously extensive and representative, and will certainly be helpful to students of the subject.

The format of the book is neat and useful. The arrangement of material is obviously the result of careful thought. Abbreviations under the references indicate the nature of the content, and taxonomic and subject indexes permit ready cross reference. Typographic errors appear to be reasonably few: I noticed a generic name in Roman type in reference 4 and "Gramasidae" for Gamasidae in reference 1581. The authors are to be complimented on the production of this excellent bibliography.

EUGENE MUNROE

A Manual of Common Beetles of Eastern North America by Elizabeth S. Dillon and Lawrence S. Dillon. Row, Peterson and Co.; Evanston, Illinois; Elmsford, New York; 1961, 884 pp., 81 plates, 544 figs. (Price $9.25).

In their preface, the Dillons state that "this book is intended for anyone interested in North American beetles — the casual naturalist, the amateur collector, the serious student, and the professional who needs a ready reference work." This objective is in general fulfilled, at least for the first two groups named.

There has long been a need for a well-illustrated, rather reasonably-priced book that will give the non-expert some general information on beetles. The present copiously illustrated book by the Dillons fills this gap to a considerable extent. About 1,200 species in 64 families are illustrated, with the scientific name, size, and brief description of the markings of the species on the page facing the beetle illustrated. Once the reader has become generally familiar with the book, he will probably be able to recognize a good percentage of the species included. If a person has a casual interest in beetles and is satisfied even if a number of the species he collects cannot be found in the book, then the book is a good investment and there is little to criticize.

On the other hand, from the professional side, the book has several major faults. In their introduction the Dillons state that only 1,200 out of a possible 10,000 species are illustrated and included. This means that nearly 9,000 species are not mentioned and this — the complete omission of any mention of what is left out of the families, subfamilies and genera — is a serious drawback. For example, in the family Scarabaeidae only the major subfamilies are given. Under the subfamily Geotrupinae (p. 523) only one genus, *Geotrupes,* is included and only four species are listed. Only a little more space would have been needed to say that the subfamily includes ten North American genera with perhaps 60 species in these genera. Also several genera omitted, such as *Eucanthus,* have fully as wide-ranging species as does *Geotrupes.* This type of omission gives a false impression of completeness that may baffle the amateur and creates a situation that any serious student may find rather frustrating.

The other major criticism, which also concerns omissions, may be directed at the bibliography.   Here, the serious student or even the professional may find a number of interesting references.   Most of these references certainly will not aid the amateur and hence the bibliography should be considered as an aid for the professional.   However, the method of selection of the papers leaves one wondering.   There are a number of obscure papers listed, but a number of more comprehensive ones are omitted.   For example, all of W. J. Brown's extensive works on the Elateridae are omitted (see pp. 837-838), while some less pertinent papers are included.

There are a number of shortcomings if one considers the work from the viewpoint of the serious worker in Coleoptera, and it is doubtful if many in this category will find the book a really useful reference.   However, I believe that the Dillons have ably achieved their primary purpose of creating a book on beetles that the non-professional coleopterist will find very useful.   The book fills a gap that has long existed in the literature on North American insects and it can be hoped and expected that it will stimulate the study of North American beetles.　　　　　　　　　　　　　　　　　　　　　　HENRY F. HOWDEN

Louis Agassiz: a Life in Science, by Edward Lurie, xii + 449 pp., ill., University of Chicago Press, Chicago 37, Ill., U.S.A., University of Toronto Press, Toronto 5, Ont., Canada, 1960.   Price $7.50.

It is notorious that scholarly and literary accomplishment do not always go together and that the most informative books are sometimes the most tedious, whereas the more readable may be made so at the sacrifice of soundness.   Such criticisms cannot be levelled at Mr. Lurie's work.   On the contrary, this book will be a tonic to those who fear the separation of scholarship from style and of science from humanism and culture.   Mr. Lurie has portrayed a notably human scientist with sympathy, comprehension, clarity and elegance.   The powerful though sometimes misdirected character of Louis Agassiz stands forth boldly in these pages.   Mr. Lurie consistently conveys the progress of Agassiz's full and active life, but on the one hand he never seems to sacrifice interesting detail or careful documentation, and on the other hand he regularly provides illuminating insights into the local, regional and international arenas in which Agassiz was such an influential protagonist.   This is a warm and vivid biography of a sincere and forceful man.   It contains moral lessons which are clearly evident even though Mr. Lurie does not belabor them.   Mr. Lurie's prose is unobtrusive but never dull.   His book should be recommended reading for all biologists.　　　　　　　　　　　　　　　　　　　　　　EUGENE MUNROE

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